Measure Identification and Analysis Plan

California Building Energy Efficiency Standards – Revisions for July 2003 Adoption

Complete Draft for November 15th-16th Workshop

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Prepared for:

California Energy Commission

Prepared by:

Eley Associates

142 Minna Street
San Francisco, California 94105
Voice 415 957 1977
Fax 415 957 1381

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Other members of the Eley Associates team made significant contributions. The following shows topic areas and those contractors responsible for each.

Topic Area	***Contractors***
Residential Envelope	Berkeley Solar Group, Lead Contractor Enercomp
Residential HVAC	Berkeley Solar Group, Lead Contractor Proctor Engineering Group Modera Consulting Engineers
Nonresidential Envelope	Eley Associates, Lead Contractor Heschong Mahone Group
Nonresidential HVAC	Taylor Engineering, Lead Contractor Felts Energy Consultants Modera Consulting Engineers CTG Energetics
Lighting (Residential and Nonresidential)	Benya Lighting Design, Lead Contractor Eley Associates Heschong Mahone Group
Water Heating	Davis Energy Group, Lead Contractor Eley Associates
Other	Eley Associates, Lead Contractor New Buildings Institute

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OVERVIEW

The purpose of this document is to identify Standards changes (measures) to be considered in the next update of the California building energy efficiency standards. The revised standards will be adopted in July 2003 and will go into effect with other *California Building Code* changes in 2005. During the interim period between adoption and the effective date, early compliance with the Standards is expected to be promoted through utility programs.

The potential changes described in this document will be presented and discussed at workshops scheduled for November 15 and 16, 2001 at the CEC. The first day will cover residential changes and the second day deals with nonresidential changes as well as changes that will impact both residential and nonresidential buildings. Following these workshops, the CEC and its contractors will consider which measures to pursue in subsequent research and which ones will not be pursued. CEC decisions will be made based on this report, proposals made by other people, comments at the workshops, and available resources.

The Standards changes described in this document are not the only ones that will be considered. Other groups and individuals are also proposing changes and developing proposals. The CEC held a workshop on October 22 to hear suggested Standards changes and presentations were made by Pacific Gas and Electric Company, Southern California Gas Company, Southern California Edison, Owens Corning, Cardinal Glass Industries, Farber Energy Design, Hirsch & Associates, the City of Seattle, Watt Stopper, and Web Service. Proponents are developing information on their suggested Standards changes using a format similar to that used in this document. These Standards changes will also be presented and discussed at the November workshops.

In the next phases of this project, the CEC staff, its contractors and proponents of other measures will do additional research on the measures that are selected for subsequent research. This research will include collecting cost data, performance information, developing performance verification procedures, and identifying or developing energy analysis methods. These tasks will be completed in the first quarter of 2002 and will be the subject of additional workshops. After that, a cost effectiveness analysis will be completed for the measures that need it, i.e., those that are recommended as mandatory or prescriptive requirements. The cost effectiveness work will be completed in the second quarter of 2002 and will be the subject of additional workshops. Early in the third quarter of 2002, a draft standard will be developed for review. Workshops and hearings will continue for about a year, leading to adoption of the Standards in July 2003.

The topics contained in this document are organized under three broad categories - Residential, Nonresidential, and Other Measures. Where appropriate, the topic titles indicate the type of Standards change: Envelope, HVAC, Water Heating, or Lighting.

Section	***Topic***	***Description***
Residential	Envelope: Residential Fenestration	Would make glazing area neutral in performance calculations up to a maximum glazing area to be determined. Would also look at cost effective U-factors and SHGC criteria.
	Envelope: Residential Construction Quality	Would consider common construction defects in residential building envelopes and make this the basecase for performance calculations. Credits would be offered for improved construction techniques with performance verification.
	HVAC: Residential Air Conditioner Sizing	Would implement sizing requirements for residential air conditioning equipment in order to address California's peak demand electricity crisis.
	HVAC: Residential Duct Systems	Would improve calculation methods for duct efficiency, and make improvements in duct insulation and duct design, and encourage ducts in conditioned space.
	HVAC: Installed Air Conditioner System Efficiency	Would look at possibly better ways to verify refrigerant charge and airflow in residential air conditioners and address actual fan power.
	HVAC: Residential HVAC System Modeling	Would modify the calculation methods for residential equipment to make performance dependent on outdoor temperatures.

Section	Topic	Description
	Water Heating: Water Heater Performance Improvement Measures	Would re-establish water heater blankets and add heat traps in the Standard Design for performance standards compliance.
	Water Heating: Central System Standard Design for Multifamily Buildings	Would modify the procedures for water heating tradeoffs to eliminate the current large credits for central water heaters in multi-family buildings.
	Water Heating: Distribution Loss Performance Improvement Options	Would require insulation for hot water pipes located in or beneath concrete slabs and consider modifications for distribution system credits and requirements.
	Water Heating: Hourly Water Heating Model for TDV Analysis	Would modify the calculation procedures for water heating to provide results on an hourly basis so that time dependent valuation of energy can be applied.
	Lighting: Definition of High Efficacy Lighting	Would define “high efficacy” lighting in lumens per watt that can be used throughout the standard. Would reduce the redundant use of definitions throughout the body of the Standard.
	Lighting: High Efficacy Lighting In Kitchens	Would redefine high efficacy lighting requirements in residential kitchens and clarify requirements.
	Lighting: High Efficacy Lighting In Utility Spaces	Would require high efficacy lighting in laundry room, utility room, garage, basement, shop, hobby room.
	Lighting: High Efficacy Lighting In Bathrooms	Would revise requirements for high efficacy lighting in residential bathrooms.
	Lighting: High Efficacy Lighting In Hotel/motel Guest Quarters	Would require high efficacy lighting in all hardwired or attached luminaires.
	Lighting: Recessed Lighting	Would limit aperture size and wattage of incandescent downlights; and require insulated ceiling air-tight housings.
	Lighting: Exterior Lighting	Would restrict exterior lighting to high efficacy sources.
	Other: Residential Replacement Windows and Other Alterations	Would establish requirements for energy efficient replacement windows and some other residential alternations.
	Other: Residential Computer Modeling	Would modify the algorithms for modeling concrete slabs, basements, cool roofs, windows and natural ventilation.
Nonresidential	Envelope: T-Bar Ceilings	Would place restrictions on the use of T-bar ceilings as the thermal barrier in nonresidential buildings.
	HVAC: Air Side Economizers	Would modify the size requirements for mandatory economizers to consider climate. Would also consider mandatory limits on economizer leakage.
	HVAC: Hydronic System Measures	Would impose requirements to make large hydronic distribution systems more efficient.
	HVAC: Duct Sealing	Would require that HVAC ducts be sealed to achieve a maximum leakage in systems that operate at 3 in. of static pressure or more, or make other changes to reflect CEC PIER projects.
	HVAC: ACM HVAC System Map and Default Systems’ Parameter Update	Would modify the HVAC system map used to specify the system to be used in the budget building. This would be a modification to the nonresidential ACM
	HVAC: Chiller Table Modifications	Would update the ARI reference standard for testing chillers from 1992 to 1998.
	HVAC: Duct and Pipe Insulation	Would increase the requirements for duct and pipe insulation, and consider the format of ASHRAE/IESNA Standard 90.1-1999.
	HVAC: Packaged Single Zone VAV	Would require either two speed motors or variable speed drives for packaged VAV systems larger than a specified size, to the extent not pre-empted by federal standards.
	HVAC: Shutoff Dampers	Would modify the shutoff damper requirement in §122 to include climate based leakage requirements and motorized dampers in the most extreme climates.

Section	Topic	Description
	HVAC: Stair and Shaft Vents	Would require a motorized damper on stair and elevator shaft vents, which are interlocked with fire and smoke detection systems.
	HVAC: VAV Fan Control Measures	Would specify the location of pressure sensors in VAV systems and require pressure reset for systems with direct digital control of individual VAV boxes.
	HVAC: Size Threshold for VAV Fan Controls	Would reevaluate the cost effective break point (fan motor horsepower) for the existing fan control requirements (currently 25 hp).
	HVAC: Zone Isolation Control Requirement	Would update the zone isolation requirement to be consistent with ASHRAE/IESNA Standard 90.1-1999. Would require that central plants have controls to allow stable operation while zones are isolated.
	Lighting: Definition of Daylit Area	Would redefine daylit area depth to be 2.5 times the height of the window.
	Lighting: Electronic Ballasts	Would make electronic ballasts required with the exception of very limited applications, to the extent not pre-empted by federal standards.
	Lighting: Variable Light Level	Would reduce the threshold mandating 50% light level capability to 0.6 WSF
	Lighting: Daylighting Controls	Would redefine the required and optional uses of automatic daylighting controls.
	Lighting: Exterior Lighting	Would make high efficacy light sources mandatory for exterior lighting applications.
	Lighting: Common Lighting Systems	Would provide new, simple compliance method based on sub 1.0 w/ft^2 method using common lighting systems.
	Lighting: Lighting Power Allowances – Complete Building Method	Would add building categories and revises some Lighting Power Densities in Table 1-M.
	Lighting: Lighting Power Allowances – Area Category Method	Would add some space categories and revises some Lighting Power Densities in Table 1-N.
	Lighting: Pulse Start Metal Halide Lamps	Would require metal halide lamps to be pulse start. Probably a Title 20 Appliance Standard
	Lighting: Existing Lighting System Alternations	Would close loopholes making lighting in alterations comply with the Standard.
	Lighting: Simplification of Tailored Method	Would simplify tailored method for the retail occupancy, resulting in easier compliance and verification.
	Lighting: Elimination of Controls Credits	Would eliminate some controls credits as a means of complying with standard.
	Lighting: Elimination of Exemption for Normally-on Emergency Systems	Would make normally on egress lighting systems part of LPD calculation.
	Other: Performance Verification of Nonresidential Systems and Equipment	Would add requirements for performance verification of specific HVAC and lighting equipment in nonresidential buildings.
Other Measures	Reconsideration of Climate Zone Boundaries	Would modify climate zone boundaries in San Diego area and south of San Jose.
	Time Dependent Valuation (TDV)	Would change the source energy multiplier currently used for evaluating performance tradeoffs for both residential and nonresidential buildings to consider time-of-use.
	Photovoltaic Systems	Would add calculation methods to the residential and nonresidential ACM manuals to address photovoltaic systems.

RESIDENTIAL

Envelope: Residential Fenestration

Description

Issues that will be studied for inclusion in the 2005 *Standards* are;

- Create package alternatives for prescriptive compliance with higher fenestration percentages, since the current restriction on fenestration percentage sometimes prevents the packages from being used. The energy impacts of increased glazing percentage may be -offset by increasing the performance of the fenestration products or - making other building features more efficient. Special treatment for west-facing glass in cooling zones will be considered due to the large impact on peak cooling loads.
- For performance calculations, Make the glazing area of the reference house in performance calculations the same as the glazing area of the proposed house up to some reasonable high value, such as 20% of conditioned floor area. Dwellings with larger glazing areas will be able to trade off the fenestration area against other features.
- Improve fenestration performance by specifying lower U-factors in the prescriptive packages. The interaction between SHGC and U-factors needs to be considered when determining the standard SHGC and U-factor values achieved by the same product type.

Benefits

The initiatives are designed to make the prescriptive and performance approaches more neutral to fenestration area with a goal of making the standards more usable for buildings with typical fenestration areas, and to make sure that dwellings with smaller glazing areas still use energy efficient fenestration products that are cost effective. The prescriptive standards will apply to a wider range of homes, making them more useful to the building industry. The impact on homes with larger fenestration areas is not clear at this time, but could lead to decreased electricity demand and energy savings. Reducing the importance of glazing area will also simplify compliance calculations and make it easier to verify compliance in the field.

By including lower U-factor products that are cost effective in the standards, energy savings and product demand will increase, and indoor comfort will improve.

No impacts are anticipated on maintenance costs, indoor air quality benefits, health and safety benefits, productivity, or increased property value. Time-dependent valuation is not expected to significantly affect the benefits derived from these changes.

Environmental Impact

To the extent that changes could increase the amount of fenestration in California, significant environmental impacts could occur. No other significant adverse environmental impacts are anticipated from these changes.

Type of Change

Changes to how fenestration is treated will likely have a significant impact on all Standards-related documents including the *Standards* themselves, the ACM Manual, the Residential Manual and the compliance forms. In the *Standards*, changes to the prescriptive approach would need to be documented. In the ACM Manual, revised rules and modeling tests would need to be developed. The Residential Manual and compliance forms would need to be revised to match requirements.

Measure Availability and Cost

Changes to fenestration performance have been a significant topic in prior proceedings. Recent studies have shown that the market penetration of vinyl frames, the most likely frame material upgrade in new construction, is now more than half the market and widely available from many different manufacturers. A new cost estimate for this upgrade will need to be established, but is likely to be less than $1/ft^2$ of fenestration area. However, for many builders, use of vinyl windows has become standard for more than just energy reasons. For them, the upgrade cost is zero. Low income housing cost impacts, especially those related to multifamily buildings, will be examined.

Useful Life, Persistence and Maintenance

For the treatment of fenestration area in both the prescriptive and performance approaches, no impacts on the life, persistence or maintenance are anticipated. For lower U-factor products, there may be issues related to the use of some types of low conductance frames, in terms of the life of the measure, which may need to be considered in the life-cycle costing calculations.

Performance Verification

The proposed changes described in this document do not modify the verification process significantly.

Cost Effectiveness

Changing the rules for the treatment of fenestration area may have cost impacts on dwellings that are typically constructed with glass areas different from the fixed glass areas in the current packages. Eliminating glazing area as a major compliance variable will possibly lead to more builders using cost effective measures.

During the last standards proceeding, low-conductance frames were shown to be cost effective under a wide range of assumptions, as is expected to be true for this proceeding as well.

Analysis Tools

The treatment of fenestration measures in computer performance calculations affects all aspects of the standards development process. The best approach would be to incorporate proposed fenestration changes into the computer performance method early in the process, so that the revised calculations can be used to establish the prescriptive packages based on their cost effectiveness.

Relationship to Other Measures

Glazing area changes alter the heating and cooling loads of residences, and therefore have a modest secondary effect on the cost effectiveness of most other measures.

Other issues related to the impact of this change also need to be considered, including the effect on buildings with different orientations, subdivision compliance using multiple orientations, and how this modeling change will impact development of the prescriptive packages. Estimating the overall impact of this change will require knowledge of the distribution of fenestration areas in California dwellings. Implementing this concept would also change a long-standing feature of computer performance compliance that there is one standard energy use for a building geometry and size in each climate zone.

Bibliography and Other Research

It may be useful to study how other building energy codes treat fenestration. One limitation of many older codes, such as those from Oregon and Washington, is that they do not effectively deal with cooling-related performance, and few except Florida's rely on performance calculations as the basis. Even older versions of the *Model Energy Code,* such as the 1993 version that is the basis of the Energy Star home program, do not address cooling related topics effectively. With growing acceptance in other states, the *2000 International Energy Conservation Code* has both a 0.40 SHGC requirement in most cooling climates and prescriptive packages that allow for more fenestration area than the California standards.

Regional Economic Research, Inc. (RER) has completed recent studies that may be useful. One study, *Residential New Construction Study* (September 2001) for Pacific Gas and Electric Company, uses on-site surveys of approximately 800 recently constructed California homes to establish typical energy efficiency characteristics, including fenestration percentages and fenestration product performance. Another RER study that may be useful is the *Low-rise Multifamily Building New Construction Characteristic Study* (July 2000) for the California Energy Commission. This study examined computer performance compliance documentation and describes typical multifamily energy efficiency characteristics, including fenestration percentage.

Additional information on recent builder practices related to fenestration can be found in the 1999 and 2000 final reports for the Builder Energy Code Training project completed by the Building Industry Institute with funding from the California Energy Commission.

Data on the types of fenestration products produced is available from the *2000 AAMA/WDMA Industry Statistical Review and Forecast,* published jointly by the American Architectural Manufacturers Association and the Window and Door Manufacturers Association.

To support an expected proposal by DOE to eliminate glazing area as a residential compliance variable in the *International Energy Conservation Code*, Pacific North West National Laboratory has prepared a white paper discussing the possibility of eliminating window-wall ratio (WWR) based requirements from residential energy codes. The proposal can be accessed at: http://www.energycodes.org/DOE_2003_Proposals.html.

Envelope: Residential Construction Quality

Description

The Residential Standards have historically demonstrated compliance primarily via hourly computer simulation. Measures installed in the house are assumed to perform at a high level, regardless of installation quality. Recent field investigations, and the increasing propensity of construction litigation lawsuits, indicate that there are frequent instances of sub par installation related to energy efficiency, primarily surrounding ducts, HVAC equipment, insulation, air barriers, and building cavities well connected to the outdoors. Many of these energy defects can be attributed to "industry standard" installation practices, which emphasize speed and simplicity over attention to detail. An added factor is that many new homes include more complicated architecture, further challenging the abilities of the field installers to identify and install a continuous and contiguous thermal and pressure envelope.

To begin to address this situation, the concept of derating measure performance to reflect industry standard installation quality has been introduced into the standards. With the 1998 Standards, residential duct leakage assumptions were modified to reflect typical installation quality, while at the same time providing a credit for certified tight ducts. Other envelope measures, which could be treated in an analogous manner, include:

- Insulation installation quality (numerous installation problems degrade envelope performance).
- Wall framing (typical measured framing factors underestimate the amount of wood in the wall cavity).
- Fireplaces and other interior cavities connected to the attic (increases uncontrolled building leakage).
- Inadequate attention to maintaining an effective air barrier (sealing, draft stopping, etc.).
- Number of recessed lights penetrating the ceiling drywall.

Crediting third-party, HERS rater-certified improved performance could also be extended to the areas listed above. Adoption of a residential construction quality initiative would also help to nurture the "house as a system" construction philosophy, which has many benefits beyond improved energy efficiency. This initiative would apply to all building types covered by the residential standards.

Benefits

Improving the installation quality of these key features improves the integrity of the building envelope. Typical construction practice results in a wide range of defects contributing to increased energy use and oversized cooling systems. Correcting these defects would lead to improved building comfort, increased customer satisfaction, reduced use of framing materials, reduced cooling system sizing (once HVAC contractors gain confidence that building envelopes perform effectively), and reduced potential for construction defect litigation. The incorporation of Time Dependent Valuation (TDV) is not expected to significantly affect the benefits derived from this initiative.

Environmental Impact

The overall environmental impact of pursuing a quality assurance construction initiative is highly favorable, with benefits accruing from both reduced resource consumption in the construction process and reduced energy use. A potential detrimental impact relates to indoor air quality, which may be adversely affected under some limited situations (e.g., very tight buildings with simple architecture and no fireplace).

Type of Change

This initiative offers different implementation options. Adjusting framing factors for typical wall construction is a simple process involving recalculation of wall U-values. Other areas, such as visual insulation inspection, require a higher level of training and appropriate rating tools for the HERS rater. The approach most consistent with recent performance-based CEC initiatives involves derating "standard" performance (of wall insulation, for example), while simultaneously providing a credit for third-party documented "improved" performance. This

modeling approach is more flexible than incorporating elements of construction quality as ***mandatory measures***, which would require the industry to undergo a rapid transformation in training, self-inspection, and quality control, and also require building officials to more closely regulate these details. The major downside of pursuing an optional credit is that it may not be accepted by the building industry if the *Standards* do not require it.

To accurately model some elements of the quality construction initiative could require minor modifications to the computer modeling tools. For example, additional wall types such as skylight shafts and kneewalls may need to be added. Implementation would require changes to the ACM and compliance documentation.

Measure Availability and Cost

There are no limitations related to specific measure availability in the area of enhanced residential construction quality. This initiative equires communicating improved installation procedures and helping the building community understand the value (i.e. compliance benefit, improved construction quality, and reduced litigation potential) of the approach. Currently, the construction industry is focused on streamlining the construction process, resulting in too little time and attention spent on the details that are critical in obtaining a finished product consistent with quality construction goals. There are likely additional costs associated with this initiative, although in the long term, cost savings arising from improved framing practice and equipment "right-sizing" may offset the additional installation labor and third-party inspections costs.

Without education of the building community, residential construction quality compliance credits may not be wholeheartedly embraced. Initial response to a compliance credit may not be strong, similar to the 1999 experience with the introduction of the tight duct credit. Insulation installers, among the lowest paid trades in the construction industry, must be better trained and compensated to competently complete their work.

One issue related to successful implementation of this initiative is whether the existing HERS infrastructure is sufficiently developed to perform the inspection task. Many HERS raters have been certified over the past few years and can be expected to competently perform a duct pressurization test following a step-by-step test method. However, a rigorous insulation and air barrier inspection requires additional understanding of where to look and what to look for. Additional education with a field-training component is likely needed to achieve the required level of competence.

The cost comparison should be relative to industry standard construction practice. Incremental costs are comprised of added labor in the installation process and third-party verification costs. The additional labor required to properly insulate, seal, and draft stop a house will vary with the complexity of the structure. On average, it is anticipated that this labor will cost about $300 per house. Third-party verification could add an additional $150 per house, less if a sampling method is used. Cost reductions could be realized from HVAC downsizing, and reduced liability insurance costs.

Useful Life, Persistence and Maintenance

This approach will provide persistent savings over the lifetime of the building and will eliminate a vast majority of the envelope defects commonly found in new homes. Equally as important, it will give the HVAC industry greater confidence in the thermal integrity of the building envelope, leading to future equipment downsizing.

Performance Verification

Performance verification is a key element of this initiative. Performance verification provides assurance to the builder and HVAC contractor that the installed building envelope (contiguous pressure and thermal barrier) meets the design intent. The HERS rater must be provided with the proper training and evaluation methodology to complete an accurate assessment of building envelope integrity. A detailed HERS-rater checklist or scorecard needs to be developed.

Cost Effectiveness

On a statewide-average basis, the residential construction quality initiative would clearly be cost-effective. Energy savings would be greatest in houses with complicated architecture (vaults, drop ceilings, cantilevered

floors, turrets, interior columns/arches, multiple recessed lights and fireplaces, etc.) in the more severe climate zones, with smaller savings seen in simple, one-story, "box type" houses with eight foot ceilings.

Analysis Tools

MICROPAS/CALRES will be used to evaluate the energy savings impact of this initiative. The tool will likely need some modification to more accurately distinguish and itemize the defects, however the scope of the necessary modifications is not large. No need exists for complicated new algorithms to accurately model relevant parameters. New wall types (such as kneewalls and skylight shafts) may need to be characterized and inputs added for new infiltration parameters (e.g. number of fireplaces, number of recessed lights).

Relationship to Other Measures

The derating of existing building envelope parameters would increase the cost effectiveness of all other space conditioning efficiency measures, depending upon the climate zone and building design.

Bibliography and Other Research

Relevant research that will assist in developing this initiative include the following:

- The CEC's Phase I RCQA report (and ongoing results from Phase II field work).
- Data and reports from LBNL's Residential Commissioning project.
- Data collected from the Building Industry Institute's training and field evaluation efforts.
- Enermodal's framing factor study for ASHRAE.
- ComfortWise and CEC building envelope protocols for energy building. Find these at http://www.comfortwise.com/ and http://www.energy.ca.gov/efficiency/qualityhomes/index.html.
- Communications with leaders and innovators in the construction quality industry (Rick Chitwood, Stan Luhr of Pacific Property Consultants, Building Science Corporation, Florida Solar Energy Center, ORNL, ConSol, others).

HVAC: Residential Air Conditioner Sizing

Description

The residential standards do not currently impose limits on the size of air conditioners that can be installed, even though the size has a major impact on peak demand for electricity. This topic area will consider ways to limit air conditioner size.

The initial proposal is that the CEC would adapt industry standard sizing calculations as published in the *ASHRAE Handbook of Fundamentals* to produce an official sizing calculation. This calculation would be made consistent with the parameters used in the ACM Manual for energy calculations and would include the effects of measures required by the prescriptive standards and other measures typically included in California houses. The sizing calculation would include rules for design temperatures, solar intensity, internal gains, window shading, and any other independent values required. Appropriate factors to allow for the incremental sizes of available air conditioning units would be included. For builders complying with the standard using the performance approach, the official calculation would be applied to the proposed design of each house, and the certified compliance software would calculate a maximum-allowed air conditioner size. The maximum size would be stated at rated conditions for comparison with published air conditioner capacities. Compliance would be demonstrated by showing that the total air conditioning capacity installed was less than the maximum allowed. There are a number of issues to be resolved in developing the sizing calculations:

1. California Measures and ACM Calculations. Current industry standard sizing calculations are difficult to use in the California compliance context because they do not include some important measures and because they do not accommodate required efficiency descriptors. For example, distribution efficiency is an important factor in California compliance and duct sealing is a prescriptive requirement for all new homes, but distribution efficiency is not included as a variable in the industry standard sizing calculations. Also, windows to be installed in new California homes are required to have SHGC ratings, and low solar gain glass is an important prescriptive requirement in cooling zones, but industry standard sizing calculations are based on defined glazing types which are not consistent with SHGC and do not include low solar gain glass. The industry standard sizing calculation will be adapted to include these and other compliance variables as inputs and to operate smoothly as part of the ACM Manual-defined performance calculation.
2. Design Data. Energy compliance is calculated based on the 16 climate zones, each of which has a standard weather file. Air conditioning sizing will need to respond to the differences in design conditions within the climate zones. However, this would mean that there is potentially a different sizing compliance requirement in each area within a climate zone.
3. Orientation. Compliance calculations for production houses are currently done with the house rotated to each of the four cardinal orientations. If the house design complies in each of the four orientations, it is deemed to comply in any orientation. If the same approach is applied to sizing, the maximum size would be calculated for four (or perhaps eight) orientations, and the largest-calculated, maximum air conditioner size would become the criteria for that design when built in any orientation. Compliance calculations for custom homes are currently done for the actual orientation of the proposed home and sizing calculations would be done using the same approach.
4. Zonal Systems and Attached Units. The industry standard sizing calculations use one set of factors for single zone houses with glass on four sides, and a different set of factors for dwelling units or zones that have glass on one or two sides. The second set of factors gives a larger air conditioner size to handle solar loads that occur during only one period, rather than being spread out over the day. The official sizing calculation will have to specify the criteria for when the second set of factors can be used and adjust for incremental capacities when multiple systems are installed in the one building.
5. Multifamily Buildings. Currently, compliance calculations for multifamily buildings are usually done for the building as a whole. Using this strategy, maximum sizing could be calculated on the same basis, adding a factor to account for the incremental sizes of available air conditioners. Compliance would be demonstrated by showing that the sum of the capacities of the air conditioners to be installed was less

than the maximum for the building. Alternatively, sizing could be developed on a unit-by-unit approach that tailors the sizing more closely to the loads for each unit.

6. Prescriptive Sizing Requirements. It may be possible to develop prescriptive maximum air conditioner sizes (Btu/h-ft²) based on climate zone that would allow a builder to demonstrate compliance without doing sizing calculations for the proposed design. This could be consistent with the current package approach to compliance. The prescriptive sizes could be developed using the official sizing method and a version of the prototype house in each climate zone. Treatment of glazing area and orientation is an important issue for the prescriptive size calculations.
7. Sizing Tradeoffs. It may be possible to accommodate those who want to install larger air conditioner capacities by using a tradeoff approach that would provide larger cooling capacity for the same kW demand. For this calculation, maximum air conditioner capacity would be converted to electrical demand kW for the air conditioning system at design conditions for minimum efficiency standard air conditioning equipment. Demand kW for the proposed building would be calculated using the same approach, allowing credit for such measures as higher on peak air conditioner EER, more efficient distribution fans, and lower static pressure in the duct system. Credit could also be allowed for installation of photovoltaic panels. Compliance would be based on showing that the net on peak demand for the proposed system is less than the demand of the maximum size standard system. Post-construction verification, perhaps including measurement of actual air conditioning system demand by a HERS rater using the house electrical meter, may be required for this approach.

Benefits

The primary benefit would be a reduction in the peak electrical demand imposed by new homes on the state's electricity supply. Data from field surveys indicates that installed air conditioners are typically larger than actually needed to meet the design load. Air conditioners operating on peak in California's hot central valley climates typically draw 1.7 kW/ton of rated capacity or more.

In addition, correctly-sized air conditioners will provide better latent load capability and increased comfort for homebuyers. Oversizing causes excess cycling, which reduces the ability to remove latent loads and makes the occupant less comfortable due to high indoor relative humidity. This situation leads to callbacks for contractors who often try making the unit bigger, thereby exacerbating the problem.

One secondary effect of sizing rules would be that building a better envelope, from a cooling load point of view (low solar gain glass, shading, cool roof, better insulation,) would result in a reduction in the allowable air conditioner size compared to providing energy compliance with other measures, such as higher AC SEER, or high efficiency heating or water heating equipment. If builders and buyers perceive a small air conditioner to be less desirable, sizing rules might become a disincentive for good envelope measures.

Environmental Impact

The positive environmental impact will result from less on peak electricity production by low efficiency peaking plants, and a reduced need for new generating capacity.

Type of Change

A requirement for residential air conditioner sizing would expand the scope of the *Standards* to require compliance with a new set of rules in addition to the current types of energy efficiency standards requirements. The change would attempt to reduce air conditioner oversizing in buildings meeting the energy standards, but it would not add new building efficiency measures.

This change will require modification of all of the Standards documents (*Standards,* ACM, Manuals, compliance forms, etc.). A new requirement for maximum air conditioner size will be added to the *Standards*. A new section will be added to the ACM Manual to define the calculation for air conditioner size. New ACM tests will be defined to verify sizing calculations. A new section will be added to the Residential Manual to explain the sizing requirement and the details of the calculations. Modifications to the compliance forms will be needed to document the size of the air conditioner and allow field verification.

Measure Availability and Cost

Air conditioner sizing calculations are available in guideline form from a variety of organizations including ASHRAE and ACCA. A number of computer implementations are available and in use in the residential HVAC industry. It is expected that sizing would be integrated into the performance method certified programs and would add very little time and effort to the calculation. Basic compliance would be relatively simple and inexpensive. Field verification, if required, would add to the cost.

Useful Life, Persistence and Maintenance

The peak demand savings provided by a smaller capacity system are very reliable and will persist as long as the system. A potential persistence issue occurs if split system outdoor units are replaced with larger capacity units after final inspection.

Performance Verification

For the standard sizing calculation approach, verification consists of simply comparing the rated capacity of the installed air conditioning units with the maximum allowed prescriptive size, or the size calculated for the building and printed on the compliance forms.

The tradeoff procedure, based on peak system kW demand, needs to be verified by a field measurement. The field measurement procedure needs to be developed and documented, including an approach allowing it to be performed at other-than-peak conditions.

Cost Effectiveness

The cost of the added sizing calculations can be compared to the value of reduced peak demand. The reduced capital cost of the smaller air conditioning system can be included. Using this approach, it is expected that sizing limits will be very cost effective.

Analysis Tools

The current Residential ACM does not calculate demand (TDV versions would add this capability). However, sizing and its benefits need be calculated separate from energy analysis, using a design conditions-oriented procedure. Commercially-available sizing software, with relatively minor modifications, should be able to duplicate the new California sizing calculation. Some certified compliance programs, Micropas for example, currently offer sizing calculations which will be adaptable to the new calculations.

Relationship to Other Measures

Sizing calculations would support the TDV analysis, which will implement models where size is an issue.

Bibliography and Other Research

2001 Handbook of Fundamentals, pages 28.1-28.6, ASHRAE, Atlanta, GA.

HVAC: Residential Duct Systems

Description

A number of modifications are being proposed in this area in order to ensure residential duct systems are both well designed and installed.

The proposed changes include:

- Duct Location and Area. Improvements to the Residential Manual will encourage the use of ducts in conditioned space and reductions in duct surface area through shorter runs.
- Unlined Flex Duct. Prohibit unlined flex ducts that use the outer vapor barrier as the only air barrier.
- Duct Design. Duct designs will match the equipment and meet accepted design criteria for flow, static pressure, and noise. The special case of duct design for multiple orientations will be addressed.
- Duct Leakage Test. Alternative duct leakage test methods, such as the Delta Q method, may be added.
- Duct Insulation. Minimum duct R-values above 4.2 will be increased.
- Duct Efficiency Calculations. The ACM Manual duct efficiency calculations will be reviewed and potentially revised to implement changes proposed in ASHRAE 152P and to simplifying requirements, where possible. This could include moving the Thermostatic Expansion Valve (TXV) credit out of the duct efficiency calculations.
- Hourly Duct Efficiency Model. An hourly variable duct efficiency model will be added to represent the impact of duct losses on peak loads. This would support the Time Dependent Valuation (TDV) modeling approach.
- Integrated Ventilation Systems. The effects of ventilation systems that are integrated with the HVAC system will be examined to determine how to assess their energy performance.

Benefits

Residential duct systems waste energy through excessive conduction losses in the winter and conduction gains in the summer. When they leak, they increase infiltration of outside air into the house, waste conditioned air, and cause pressure differentials that can result in the failure of combustion venting systems to operate as designed. When they are well designed and installed, the systems provide lower energy consumption and greater comfort. The savings from efficient ducts are largest at peak electrical consumption periods in summer and winter.

TDV would further reveal the outstanding peak reduction benefits of these measures.

Environmental Impact

The environmental impacts from these potential changes would be mostly positive. Indoor air quality is improved if leakage-induced pressure differentials are reduced to pull less contaminants from attics, garages, and crawlspaces into return ducts. Environmental emissions are lower because of the reduced annual energy consumption and, more importantly, because of the reduced consumption on peak when higher emitting power plants are on line. A potential increased consumption of insulation materials may occur if there is a higher duct insulation requirement, but a potential reduction in the consumption of duct material will result if there are shorter ducts or if ducts are inside conditioned space.

Type of Change

These changes could be addressed as noted below. The best method of implementing these changes will be discussed.

- Duct Location and Area. The Residential Manual would promote a more widespread use of ducts in conditioned space as well as shorter duct runs by providing more thorough explanation of effective approaches and design considerations. This would not entail any new minimum compliance requirements.
- Unlined Flex Duct. The elimination of unlined flex ducts that use the outer vapor barrier as the only air barrier would be implemented as a mandatory measure. All the Standards documents would have to be revised to reflect this new requirement.
- Duct Design. The implementation of duct designs matched to the equipment and meeting accepted design criteria could be addressed as a prescriptive requirement, mandatory measure, or compliance option. If it were a mandatory measure, it would provide increased requirements on duct systems. It would replace the current ACCA Manual D credit with a simpler and better defined set of criteria. All the Standards documents would have to be revised.
- Duct Leakage Test. Providing alternative duct leakage test methods would call for a new compliance option. There are a number of new tests being investigated, including the Delta Q method, which may provide more accurate estimates of the duct performance and may be more easily implemented under certain circumstances.
- Duct Insulation. Increased duct R-values above 4.2 would be considered a revision to prescriptive requirements.
- Duct Efficiency Calculations. Simplifying and changing duct efficiency calculations based on recent research would require revisions to the ACM Manual for duct efficiency. Consequences on the stringency of the Standards, if any, would need to be evaluated.
- Hourly Duct Efficiency Model. This is an ACM Manual modeling change.
- Integrated Ventilation Systems. Also an ACM Manual modeling change, this proposal would require the energy use related to ventilation systems to be included in compliance calculations.

Measure Availability and Cost

- Duct Location And Area. Currently, only the most sophisticated builders address duct locations, terminal locations, and duct length. Most provide only minimal direction to the installing contractor. With the proposed change, there would be increased design time to bring the ducts into conditioned space or to specify alternative terminal locations (high inside wall or central in the ceiling). The effect would be slightly higher design costs, with the potential for lower materials costs (shorter ducts), smaller compressors, and lower installation costs. The cost of revised home designs that allow proper areas for duct runs will be investigated, and information will be supplied in the manuals on the most cost effective approaches.
- Unlined Flex Duct. Manufacturers produce a variety of flex ducts. Some of them have no inner air barrier, but depend on the integrity of the outside vapor barrier to contain the air, which has a high potential for failure. However, manufacturers have sufficient alternative products.
- Duct Design. ACCA Manual D, SMACNA, ASHRAE, and others all have duct design criteria. However, these criteria are routinely ignored in practice. The cost of a system designed to adequate criteria varies. The costs depend on the size of the heating and cooling source, the selection of the air handler, and the expertise of the designer. A well-designed system by an expert designer should be no more costly than a standard design, particularly if the design is used on multiple buildings.
- Duct Leakage Test. The current duct leakage tests require specialized equipment, which is now widely available in California. The additional test procedures under consideration would allow the use of different specialized equipment. Manufacturers exist for all the equipment that would be allowed and they can provide sufficient quantities for use. The potential alternative tests may be less expensive under some circumstances.
- Duct Insulation. Higher R-value ducts are available from multiple manufacturers. The higher R-value ducts are more expensive, but may be justified by life-cycle cost analysis. Higher R-values are

currently required by the *International Energy Conservation Code* and have been adopted by other western states.

- Duct Efficiency Calculations. Duct efficiency calculations are already implemented in the standard. These calculations and verification might be simplified. If so, the costs would be reduced.
- Hourly Duct Efficiency Model. This computer modeling change will be invisible to the user.
- Integrated Ventilation Systems. This is an ACM Manual modeling change.

Useful Life, Persistence and Maintenance

These measures have lifetimes approaching the life of the home, with no maintenance or persistence issues.

Performance Verification

The current *Standard* requires verification for: Duct Leakage Reduction, Duct Design, Duct Surface Reduction, and Duct Location better than the Default Location. The changes proposed should have verification requirements sufficient to ensure high performance for the substantial majority of the installations, without causing undue economic burden or time delays to building completion.

Cost Effectiveness

Any changes to the mandatory measures and prescriptive requirements will be shown to be cost effective relative to the current standard. Compliance options are very likely to be cost effective compared to current standard.

Analysis Tools

The primary analysis tools for these changes will be duct efficiency simulation models. These models include ASHRAE 152P, the FSEC Duct Model, and the Proctor Engineering Group Duct/AC Model. Secondary tools are ACCA Manual D and ASHRAE calculations contained in the *ASHRAE Handbooks*.

Relationship to Other Measures

The efficiency of the duct system is quite dependent on the sizing and airflow of heating and cooling equipment.

Bibliography and Other Research

Researchers and contractors active in duct issues will be consulted and recent publications will be reviewed. The following is of particular interest:

ASHRAE 152P - Method of Test for Determining the Design and Seasonal Efficiencies of Residential Thermal Distribution Systems.

HVAC: Installed Air Conditioner System Efficiency

Description

The proposed changes for residential buildings are:

1. Refrigerant and Evaporator Airflow. AB 970 changes implemented a prescriptive requirement for verified refrigerant charge and airflow. Due to this new option, a review of, and possibly change to, the calculations, methods of test, or methods of verification based on recent studies will occur. In addition, the refrigerant charge and airflow could be extended to apply to TXV systems, an option which is currently not allowed. The AB 970 changes also extended the refrigerant charge and airflow measure to replacement air conditioners. This area will be reviewed.
2. Fan Power. In the calculation for the seasonal energy efficiency ratio (SEER), the assumption is that air handlers consume 365 W/1000 cfm, but there is no test or standard for the power of air handler fan/motor assemblies. The result is that fan power generally exceeds 500 Watts and often approaches 1000 Watts. Under the proposed change, a method would be developed to account for fan watt draw and an option provided for a credit for reducing fan power. This specification could include verification of fan power or other significant variables at the installation. It could also include specifications of particular fan/motor assemblies that have a certified level of efficiency. This change would revisit the calculations associated with the installed air conditioner efficiency.

Benefits

Residential air conditioning systems waste energy because they operate at efficiencies below their laboratory efficiencies. This factor is due to a number of widespread installation issues, including incorrect refrigerant charge, improper evacuation, low evaporator airflow, and high static pressures. Obtaining an installation that has proper refrigerant charge, proper evaporator airflow, reasonable static pressures, and lower fan watt draw reduces energy consumption, and is particularly effective at reducing peak electrical consumption.

Correct refrigerant charge and airflow produce more even-delivery temperatures and higher comfort, while reducing fossil fuel emissions. Units with proper airflow produce more sensible capacity, which is needed in California's hot dry climates. Units with too much or too little charge are more prone to compressor failure and higher repair costs.

Changes or alternatives to the airflow test methods could increase the number of units with correct airflow. Changes in verification techniques could lower the cost, and increase the percentage, of units implementing these measures.

Improved installation practices promoted through these changes are likely to raise the level of these practices; thus reducing the amount of ozone-depleting R-22 released into the atmosphere.

Time Dependent Valuation would point out the outstanding peak reduction benefits of these measures.

Environmental Impact

These changes produce only positive environmental impacts. Environmental emissions are lowered because of the reduced annual energy consumption and, more importantly, because of the reduced consumption on peak, when the more polluting power plants are on line.

Type of Change

The refrigerant and evaporator airflow changes would modify the requirements in the TXV/Airflow-Charge portion of Prescriptive Package D.

The fan watt draw changes would also be implemented as revisions to the TXV/Airflow-Charge portion of Prescriptive Package D. A new requirement related to reducing actual fan power would be added. An

investigation will determine whether this limit should be stated in terms of floor area, air flow, or compressor capacity. All the Standards documents would have to be revised.

Measure Availability and Cost

Testing and obtaining proper refrigerant charge and evaporator airflow has been taught and practiced in California in the recent past. Utility and CEC programs have trained technicians in the proper application of the Title 24 specifications, and compliance is within the grasp of any competent installer. There is no additional labor cost associated with meeting the standard for a contractor who is currently checking charge and airflow as specified by the manufacturer. The cost of verification varies with the package of measures, and whether this is a single installation or part of a development.

For fan watt draw, air-handler fan/motor assemblies come in a variety of efficiencies. The installed efficiency is largely dependent on the quality of the duct system design and installation. Various manufacturers offer higher efficiency fan motors in a number of air handlers. These high efficiency fan motors are substantially more expensive than standard fan motors. Properly designed duct systems, with lower static pressure and attention to the inlets to the fan box, may be more cost effective than the high efficiency fan motors in achieving adequate airflow with lower watt draw than currently seen in the field.

Useful Life, Persistence and Maintenance

Over the life of the system, adequate airflow provides improved efficiency compared to systems that have inadequate airflow. Subsequent events may reduce the airflow of either system, but the system that started with better airflow and efficiency will remain better.

Performance Verification

The current *Standard* requires verification for TXVs, as well as charge and airflow. The changes proposed should have verification requirements sufficient to ensure high performance for the substantial majority of the time, without causing undue economic burden or time delays to building completion. Installation of an air-handler with a high efficiency fan/motor assembly could be verified by checking the model number of the fan motor. Adequate airflow verification could require measurement of total airflow. Fan watt draw could be verified using the utility electric meter.

Cost Effectiveness

The cost and estimated savings will be analyzed to determine cost effectiveness for each proposal. Charge and airflow verification for TXV systems will cost the same as it does for systems without TXVs. Because of the effect of the TXV, there will be less energy and demand savings than on a system that does not have a TXV, however this verification is still expected to be cost effective.

Analysis Tools

The primary analysis tools for these changes will be the energy and peak consumption simulation models developed by Proctor Engineering Group.

Relationship to Other Measures

The efficiency of the duct system is quite dependent on cooling equipment airflow and performance. When third-party verification is required, the cost per measure is reduced when multiple tests can be completed at the same time.

Bibliography and Other Research

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U. S. Government, Federal Register, Vol. 64, No. 226, Wednesday, November 24, 1999, Proposed Rules Department of Energy, Office of Energy Efficiency and Renewable Energy, 10CFR Part 430 [Docket No. EE-RM/STD-98-440], pp. 66306 – 66340.

HVAC: Residential HVAC System Modeling

Description

This change would add hourly HVAC system models to the Residential ACM to allow Time Dependent Valuation (TDV) calculations and improve seasonal efficiency estimates. The current Residential ACM uses an hourly sensible loads model for the building envelope, but HVAC system effects are accounted for using seasonal efficiencies only. The proposed models will adapt the DOE-2 system model approach that uses a series of equations to relate the performance of the system to weather, indoor conditions, and part load. Major components of this change are:

1. Air Conditioner Model. Hourly air conditioner energy will be calculated, including the effects of outdoor dry bulb temperature and indoor humidity on the capacity and efficiency of the compressor. The effect of part load cycling on efficiency will also be included. Default relationships based on recent and ongoing laboratory tests for performance at high outdoor temperatures will be included. Additional inputs (such as EER95 and/or EER and capacity at 80 F) that would better account for the characteristics of individual systems may be included. Special accommodations will be made to give fair treatment to ground source and possibly also evaporatively cooled compressors.
2. Heat Pump Model. The capacity and efficiency of the heat pump compressor, including the effect of outdoor temperature, will be accounted for. Backup strip heat will be assumed to meet the load if the compressor capacity is inadequate.
3. Other Heating. The efficiency of furnaces and other heating systems is very insensitive to hourly temperatures and part load conditions. The hourly energy use of these systems will be calculated using seasonal efficiency factors applied hourly.
4. Distribution Efficiency. For ducts in attics, a new hourly distribution efficiency multiplier will provide variation in response to the combined effect of outdoor temperature and solar radiation. This model, produced as part of the TDV project, will preserve the overall ACM seasonal distribution efficiencies, but give realistic effects for the on peak performance of distribution systems.
5. Simple Latent Model. A simple latent load model that estimates the additional load due to latent internal gains and infiltration will be included.
6. Compressor Sizing. If the proposal to implement sizing rules and requirements is carried forward, the calculated compressor size would be used in the hourly HVAC system calculations. If sizing is not implemented in the *Standards*, a default size, intended to represent the average relationship of compressor size to actual load, will be implemented. Heat pump compressor size will default to the size calculated for the air conditioner. Optional input for the size of the heat pump compressor will be considered.

Benefits

The primary benefit of these changes will be to allow the correct tradeoffs for measures that have large effects on peak electricity use and demand. These tradeoffs are required for the accurate calculations of TDV energy use. These changes will increase the compliance value of design choices that have large on peak energy use effects.

Environmental Impact

These changes will have a positive environmental impact, as builders choose measures that reduce on peak consumption, thereby reducing demand for peak powerplants, which are significantly less efficient and more polluting than baseload plants.

Type of Change

The change would modify the calculation procedures or assumptions used in making performance calculations. This change would not add a compliance option or a new requirement, but would affect the way that tradeoffs are made.

This change would require extensive modifications to the Residential ACM Manual to describe the new models and their inputs, and to define or revise the tests.

Measure Availability and Cost

N/A

Useful Life, Persistence and Maintenance

N/A

Performance Verification

Default hourly performance can be assumed with little additional compliance verification beyond what is currently required. The compressor capacity of a heat pump system is an important variable that will probably need to be verified in the field. If additional performance characteristic inputs are allowed, additional field verification will be required. If EER is allowed as a compliance alternative, third party field verification of the EER used for compliance will be required.

Cost Effectiveness

N/A

Analysis Tools

N/A

Relationship to Other Measures

The implementation of TDV energy accounting makes this change very important.

Bibliography and Other Research

DOE2 Engineers Manual (2.1A). NTIS Order Number DE-830-04575.

Water Heating: Water Heater Performance Improvement Measures

Description

This measure proposes to re-establish the standard design water heater blanket requirement, which had been dropped as part of the design for performance standards in the 1998 Standards, even though it remained a requirement for water heaters with less than 0.58 EF.

This measure also proposes the addition of a requirement for heat traps. The federal energy factor standard for gas water heaters, in effect since 1990, has been EF = 0.62 - 0.0019 x volume, or 0.54 for a 40-gallon water heater and 0.525 for a 50-gallon water heater.. In 2000, the U.S. DOE adopted new federal standards that changed the constant value in the equation to 0.67, resulting in a minimum energy factor of 0.59 for a 40-gallon water heater and 0.575 for a 50-gallon water heater. In California, water heaters with energy factors of 0.62 for 40-gallons and 0.60 for 50-gallons are widely available, at virtually no additional cost. The measure would avoid compliance loopholes created by a difference between standard design requirements and readily available, cost-effective water heater efficiencies. This measure applies to single family and multifamily residential buildings.

Benefits

The principal benefit is to reduce energy use by requiring more energy efficient water heating equipment and systems. The federal standards have not been updated since 1989 and the next improvements will not take effect until 2004. Equipment on the market in California is 10% more efficient than the federal standards. The gap between the federal standard and commonly available equipment erodes the stringency of the standard when the performance method of compliance is used. The proposed modifications are likely to induce builders to use higher efficiency water heaters that are readily available at little or no added cost, instead of installing blankets and heat traps. In either event, cost-effective energy savings will be realized and a trade-off loophole will be eliminated.

Environmental Impact

The proposed measure will have no foreseeable adverse environmental impacts, and has the potential to reduce carbon and NOX emissions, due to savings from closing loopholes that currently allow cooling or heating energy to be unnecessarily increased.

Type of Change

There are a couple of ways that the proposed measures may be implemented. The requirement for a heat trap and external insulation would likely be included as a mandatory measure with an exception for water heaters with a high energy factor. The Residential ACM Manual would be modified to include calculations of the energy savings for water heater blankets and heat traps.

Measure Availability and Cost

Water heater blankets and heat traps are readily available, and are distributed through common wholesale and retail channels. Since water heaters in the range of 0.60 to 0.62 EF are easily obtainable, they will likely continue to be used in new California residences to comply with the *Standards*, instead of installing water heater blankets and, perhaps, instead of heat traps. The baseline condition for life-cycle cost analysis is a gas water heater without a blanket or heat trap that meets the minimum federal energy factor standard. The total installed cost of the measure would be based on application of the blanket and heat trap. Blankets and heat traps probably range from $20-30 total.

Useful Life, Persistence and Maintenance

Excepting possible noise problems sometimes experienced with ball-type heat traps, maintenance costs will be minimal and persistence excellent. Water heater blankets in exposed locations may be subject to damage

from exposure or tampering. High efficiency water heaters, installed in lieu of the blanket/heat trap requirement, should have similar persistence as current standard efficiency units.

Performance Verification

No performance verification is needed for this measure. Improperly installed heat traps (ball type) will prevent hot water flow and are easily detected prior to occupancy. Water heater blankets and heat traps, and/or water heater nameplate data, can be checked coincident with inspections for seismic strapping.

Cost Effectiveness

LBNL developed the WHAM water heater simulation model, which can be used to assess the energy savings value of water heater blankets. Other literature sources can provide information on the energy savings value of heat traps. Installation cost data will be obtained through surveys of suppliers and contractors. Calculations will be completed using 2003/2005 *Standards* economic assumptions.

Analysis Tools

LBNL's WHAM model is the only analytical tool needed to quantify energy savings and peak demand reduction resulting from the application of external insulation. To quantify demand savings, it will be necessary to test several different hot water load profiles using the WHAM model.

Relationship to Other Measures

There are likely to be interactions between this measure and other proposed water heating measures.

Bibliography and Other Research

Eley Associates completed research on time-dependent value that employed the WHAM model.

Water Heating: Central System Standard Design for Multifamily Buildings

Description

One of the loopholes identified in the existing water heating methodology relates to multifamily buildings. The baseline water heating budget for all building types is one storage water heater per dwelling unit. Because of the large amount of standby loss associated with each individual water heater, a substantial energy credit can be obtained by installing central water heating systems. This credit can be traded-off against envelope and HVAC equipment options, resulting in a below-standard building design that, unfortunately, has excellent persistence. To close this loophole, the proposed measure establishes a central system as the standard design for multifamily buildings that install central system water heating.

Benefits

In addition to closing a major loophole, this measure assures that building envelope designs will not depart substantially from cost-effective prescriptive standards levels, which will likely lead to major energy savings and peak demand reductions in these buildings.

Environmental Impact

The change will reduce energy use, thereby decreasing emissions from electric power plants and natural gas heating appliances.

Type of Change

This change would alter prescriptive requirements in terms of modifying the baseline in multifamily buildings. The *Standards*, ACM Manual, and compliance forms would all be affected by these changes.

Measure Availability and Cost

In those cases where multifamily builders took advantage of the loophole, this measure will increase construction cost by an unknown (but cost-effective) amount. This measure has no availability issues.

Useful Life, Persistence and Maintenance

There are no issues related to this topic.

Performance Verification

Performance verification is not required.

Cost Effectiveness

Multifamily buildings with central water heating systems will be required to install measures that have previously been shown to be cost-effective.

Analysis Tools

The tools used to develop current compliance methods (spreadsheet calculations and the HWSIM distribution loss model), and perhaps LBNL's WHAM model, will be used. Multifamily distribution loss calculations should be revisited as part of this work. Enhancements introduced as part of other water heating methods would be applied to this measure when appropriate.

Relationship to Other Measures

The closing of the multifamily central water heating loophole will affect other measures to be implemented in achieving compliance. Other residential buildings will not be significantly affected.

Bibliography and Other Research

The following data is available and will be reviewed in the course of this work:

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USDOE Technical support document on water heating, 2000.

LBL-37805. *Modeling Patterns of Hot Water Use in Households*, November 1996. Includes information on use patterns and description of the WHAM model.

TDV studies completed for PG&E.

Water heating load profile data from various sources, including PG&E.

Experts to be contacted include:

Jim Lutz, LBNL.

Frank Stanonik, GAMA.

Water Heating: Distribution Loss Performance Improvement Options

Description

Distribution loss, and its impact on residential energy use, was evaluated in detail in the 1990s to develop the compliance procedures currently in use. For the 2005 *Standards*, a more-detailed investigation of distribution losses is proposed to address several issues needing further study. Specific measures being proposed for re-evaluation include: insulation of hot water piping including piping under slabs; pipe size; distribution losses for large custom homes that are outside the bounds of the assumptions implicit in the *Standards*; and appropriateness of current calculations for all recirculating systems including losses from recirculating hot water systems for single family and multifamily buildings. This evaluation will include the possibility of more accurately quantifying high energy usage of poorly designed systems making room for credits for better performing systems and considering alternative methods of achieving high efficiency distribution systems. TDV accounting will also require reevaluation of distribution losses.

Benefits

Refining distribution loss assumptions will improve the accuracy of compliance calculations. These improvements are expected to more accurately calculate the high energy use of poorly designed systems, and result in significant energy savings and demand reduction.

Environmental Impact

The environmental impacts of this measure are projected to be favorable.

Type of Change

The proposed changes will affect the *Standards'* baseline and modeling assumptions. The distribution system compliance options, particularly for continuous recirculating systems, poorly designed distribution systems, and more effective options, would also be modified as result of this work. Changes may in include requiring insulation on hot water pipes including those slabs and disallowing pipe diameters larger than inlet pipes. Under-slab pipe insulation, if deemed cost-effective, would be a mandatory measure. The *Standards*, ACM manual, and compliance forms will be affected by these changes. Labeling of insulation with the R-value may be considered to aid inspection.

Measure Availability and Cost

The cost of implementing the pipe insulation measure can be readily determined for individual projects; however, an assumption of "length of insulation per square foot of house" needs to be developed before a "standard" cost can be identified. There are no maintenance costs. Insulation is widely available from plumbing suppliers, and is already required for hot water recirculation systems. Other measures, which would add to construction costs, may be identified in the course of re-evaluating distribution loss. The baseline condition for pipe insulation would be a typical house with un-insulated hot water piping in the attic and below the slab, which are currently common practices.

Useful Life, Persistence and Maintenance

The lifetime of the commonly-used, expanded polyethylene insulation in under-slab locations should be greater than 50 years, although there are no known studies in this area. Persistence and maintenance issues need to be evaluated.

Performance Verification

Insulation can be inspected coincident with the rough-in plumbing inspection. There are no verification or commissioning costs. Performance verification is not currently expected to be required.

Cost Effectiveness

In previous standards development work, under-slab pipe insulation was found to be marginally cost-effective, because it only provides benefit when the interval between draws is fairly short. Thus, cost-effectiveness depends upon the assumed piping design and draw schedule. Investigations completed using more recent data on piping design and draws may lead to different conclusions. With TDV considerations, insulation is very likely to be cost-effective for electric water heating systems.

Analysis Tools

The HWSIM model, used in the development of the distribution loss assumptions in the current standards, still appears to be the best available evaluation tool for distribution system losses. The existing water heating methodology, the HWSIM distribution loss model used in the 1991 work, and the WHAM model will be employed to determine the overall effect of distribution system design alternatives, including pipe insulation. It may be necessary to develop an additional model for simulating loss of large recirculation systems or to use with the DOE2 simulation program for analysis purposes.

Relationship to Other Measures

There are likely to be interactions between this measure and other proposed water heating measures.

Bibliography and Other Research

The following data is available and will be reviewed in the course of this work:

Davis Energy Group. *California Residential Water Heating Standards – Volumes I – III, 1991*. These volumes represent the technical basis for the existing water heating standards.

Davis Energy Group. *Parallel Piping Studies*, 1991.

USDOE Technical support document on water heating, 2000.

LBL-37805. *Modeling Patterns of Hot Water Use in Households*, November 1996. Includes information on use patterns and description of the WHAM model.

TDV studies completed for PG&E.

Water heating load profile data from various sources, including PG&E.

CEC PIER Project on water heating distribution systems, DEG and ORNL Contractors

Experts to be contacted include:

Jim Lutz, LBNL.

Frank Stanonik, GAMA.

Water Heating: Hourly Water Heating Model for TDV Analysis

Description

Current water heating algorithms calculate water heating budgets based on annual calculations. To effectively use TDV, algorithms must be developed which accurately convert the annual calculations to an hourly basis. This proposal should not have any affect on the balance between standard and proposed DHW budgets, only on the tabulation of energy use by hour. This change would affect all building types covered by the residential *Standards*.

Benefits

Since natural gas (or propane) water heaters are installed in virtually all new California construction, the state-wide impact of TDV on water heating will be most significant for continuous recirculating systems .

Environmental Impact

The primary impact is expected to be due to savings associated with continuous recirculating systems. ,

Type of Change

The proposed changes will affect the modeling assumptions for both standard and proposed buildings. The changes would affect the ACM, but would likely not affect other compliance documents, manuals, or analysis tool documentation.

Measure Availability and Cost

N/A.

Useful Life, Persistence and Maintenance

N/A.

Performance Verification

N/A.

Cost Effectiveness

N/A.

Analysis Tools

The existing water heating methodology will be the starting point for evaluation of TDV impacts. The algorithms will be reviewed to determine the necessary modifications to complete hourly calculations. Annual energy use under the existing method and the TDV method would be compared to ensure consistency.

Relationship to Other Measures

There are likely to be interactions between this measure and other proposed water heating measures.

Bibliography and Other Research

The following data is available and will be reviewed in the course of this work:

Davis Energy Group. *California Residential Water Heating Standards – Volumes I – III, 1991*. These volumes represent the technical basis for the existing water heating standards.

USDOE Technical support document on water heating.

TDV studies completed for PG&E by Eley Associates.

Experts to be contacted include:

Jim Lutz, LBNL.

Lighting: Definition of High Efficacy Lighting

Description

High efficacy lighting is required in many places in the standard for both residential and nonresidential buildings. This *Standards* change would consider a single definition of high efficacy lighting, enabling the code language to be simplified, e.g. the lumens per watt do not have to be repeatedly specified. The definition is stated in terms of lamp watts only, making it easier to verify compliance. The definitions are intended to be parallel with existing definitions from residential lighting (40 LPW) and exterior lighting (60 LPW), but modified to only include lamp watts.

> ***§101** Definitions*
>
> *HIGH EFFICACY LIGHTING, for the purposes of this Standard, is defined as follows:*
>
> *1. At least 55 initial lumens per watt for lamps rated at 40 watts or less*
>
> *2, At least 65 initial lumens per watt for lamps rated at 41 watts or greater*
>
> *High efficacy luminaires shall not contain medium base incandescent lamp sockets (line voltage). In calculating the lumens per watt, only the watts of the lamp (not the ballast) are to be considered. A high efficacy luminaire is a luminaire containing high efficacy source(s).*

The following are examples of typical lamps with the efficacy calculated using the recommended method.

Lamp	Initial Lumens	Lamp Watts	Lumens/Watt
PL13 lamp	900	13	69
PLC26 lamp	1800	26	69
PLT32 lamp	2400	32	75
F40T12CW lamp	3150	40	78
F32T8/7XX lamp	2850	32	89
M35 lamp	2500	39	64
M70 lamp	5000	70	71

Benefits

This measure simplifies the *Standards* by standardizing an important definition, and permits periodic updating of the lumens/watt thresholds without making changes in multiple sections. It eliminates complications of evaluating ballast types, e.g. lumens per watt include only the lamp watts, while increasing minimum efficacy of low wattage sources.

Environmental Impact

No significant change.

Type of Change

High efficacy lighting sources are required mainly through mandatory measures. This *Standards* change would affect these requirements.

Measure Availability and Cost

This *Standards* change does not significantly change the requirements; rather, it is a simplification of existing language.

Useful Life, Persistence and Maintenance

Not applicable for this *Standards* change.

Performance Verification

No performance verification is required for this *Standards* change.

Cost Effectiveness

Cost effectiveness calculations are not required since this is a simplification of the language.

Analysis Tools

No analysis tools are needed to implement this *Standards* change.

Relationship to Other Measures

This definition is intended to be used in other measures to simplify and standardize language. It becomes a universal standard useful in specific sections affecting residential interior lighting, residential exterior lighting, and exterior lighting for commercial facilities.

Bibliography and Other Research

The *Advanced Lighting Guidelines* and other sources provide data on lamp power and output. Data is also commonly available from product manufacturers.

Lighting: High Efficacy Lighting In Kitchens

Description

The current requirements for residential kitchens mandate the use a high efficacy source for general lighting. This mandatory measure is contained in §150(k). The Commission has had difficulty in defining the term "general lighting" in a fashion that resulted in consistent enforcement of the requirement. An entire issue of the *Blueprint* (#62, Spring 2000) was dedicated to this problem. Alternatives published in this *Blueprint* were incorporated into the 2001 Residential Manual.

This proposed *Standards* change would provide a simple method to field-assess a lighting installation on the basis of watts alone, by requiring that at least 50% of the kitchen lighting wattage be high-efficacy sources. Other simple compliance methods described in *Blueprint 62* will also be evaluated for possible adoption into the *Standards*.

> ***§150(k)*** *Luminaires installed in kitchens shall employ high efficacy sources for at least (50%) of rated lamp watts of permanently installed lighting. High efficacy luminaires installed to meet this requirement shall be on separate switches from any incandescent lighting. High efficacy lighting shall be controlled by the most accessible switch(es) in the space.*

Benefits

Simpler requirements improve enforcement and compliance. This change provides a clear means to achieve a significant amount of high efficacy lighting in kitchens, and reduces gaming and subjective evaluations, e.g. defining the difference between general vs. task lighting in residential kitchens.

Environmental Impact

This measure may increase the amount of high efficacy lighting in residences, therefore saving energy. Fluorescent and other high efficacy sources contain a small amount of mercury. Mercury is also produced at power plants, and studies show that the energy savings at power plants related to high efficacy sources reduces mercury pollution more than what is added locally from the use of fluorescent lighting. Furthermore, power plant emissions are airborne, which produces more damaging effects.

Type of Change

This requirement is a mandatory measure.

Measure Availability and Cost

High efficacy luminaires have been shown to be cost effective time-and-time again when compared to more conventional incandescent sources, especially when lamp replacements and maintenance costs are factored in.

Useful Life, Persistence and Maintenance

High efficacy luminaries last longer than incandescent luminaires. It is recommended that screw-in, compact fluorescent lamps be prohibited for compliance purposes because when they fail, they would likely be replaced by incandescent sources.

Performance Verification

Performance verification is not required for this measure, other than standard plan checking and field inspection activities.

Cost Effectiveness

No significant change is proposed to the existing standard. However, the cost effectiveness of high efficacy sources in residential kitchen applications will be demonstrated in later project research. In this subsequent research, model designs will be developed to demonstrate the implications of this requirement. As an example, assuming 60 LPW for high efficacy sources and 20 LPW for low efficacy sources, the requirement would result in about 75% of the light in a kitchen (by lumens) being provided by the high efficacy sources. The proper balance between normal and high efficacy sources will be evaluated in design models during later phases.

Analysis Tools

Models used to demonstrate the effects of this new rule can easily be created using ordinary design tools and available data.

Relationship to Other Measures

This requirement uses the “high efficacy source” definition.

Bibliography and Other Research

The *Advanced Lighting Guidelines*, manufacturers’ literature, the *IESNA Handbook,* and multiple other sources provide information on the benefits of high efficacy sources.

Lighting: High Efficacy Lighting In Utility Spaces

Description

This proposed new requirement requires high efficacy lighting in laundry rooms, utility rooms, garages, basements, shops, hobby rooms, etc. The requirement would only apply to permanently mounted luminaires. The following language would be added to §150 of the *Standards*.

> ***§150 (k)***
>
> *Luminaires installed in the following rooms shall employ high efficacy source(s)*
>
> *1. Laundry room*
>
> *2. Utility room*
>
> *3. Garage*
>
> *4. Basement utility areas*
>
> *5. Work room, shop or hobby room*

Benefits

This requirement mandates high efficacy lighting in residential spaces (other than kitchens and baths), where it is appropriate and cost effective. The requirement would result in significant energy savings with ancillary environmental benefits.

Environmental Impact

This requirement will increase the amount of high efficacy lighting in residences, therefore saving energy. While high efficacy sources contain a small amount of mercury, the benefit of mercury reductions at power plants outweigh this impact when emissions and waste are considered at a regional scale.

Type of Change

This requirement would be implemented as a mandatory measure.

Measure Availability and Cost

Equipment similar to what is already required for residential kitchens and baths (see above) would be used in this measure as well. This equipment is commonly available at a reasonable cost from multiple manufacturers.

Useful Life, Persistence and Maintenance

High efficacy lighting lasts longer than the incandescent equipment it would replace. Persistence of savings is provided by a restriction on medium-based sockets (see definition of high efficacy lighting).

Performance Verification

No special requirements for performance verification are needed. Standard plan checking and field inspection activities are necessary, as with all other Standards requirements.

Cost Effectiveness

As part of the follow up research, the annual hours of lighting use needed to justify the switch from incandescent to high efficacy sources will be calculated. These threshold hours will be compared to typical lighting hours in the residential spaces where the requirement applies.

Analysis Tools

Annual energy use figures for cost effectiveness purposes can be determined by multiplying the estimated lighting hours by the estimated power of each lighting system considered. Reduced lighting power also has cooling benefits in air-conditioned buildings. This benefit will also be quantified and factored into the analysis. CALRES or MICROPAS will be used for this purpose.

Relationship to Other Measures

This measure uses the term “high efficacy lighting” which is generally defined (see above).

Bibliography and Other Research

Research conducted by the Heschong Mahone Group (HMG) for the ALAC has estimates of residential lighting hours in residential buildings. This data is also used in the California Lighting Model, a joint project of HMG and Eley Associates for the CEC. These data will provide estimates of lighting hours in typical residential spaces. The power savings associated with high efficacy lighting will be determined by typical incandescent and high efficacy lighting equipment commonly used in residential applications.

Lighting: High Efficacy Lighting In Bathrooms

Description

This standards change will address problems associated with the existing high efficacy lighting requirement for residential baths. This requirement is one of the most unpopular requirements for builders because fluorescent lighting is perceived as being poor quality, especially vanity lighting in master bedrooms. Some of the issues and CEC interpretations are provided in the Spring 2000 *Blueprint*. Several options will be explored to make the requirement more understandable and more enforceable. The following language for §150 is one option for addressing the problem.

> ***§150***
>
> *Each room containing a water closet, sink, tub, or shower shall have at least one luminaire that qualifies as high efficacy lighting. If there is more than one luminaire in the room, the high efficacy luminaire shall be switched at the entrance to the room.*

Other options may also be explored, including requiring that a percentage of permanently installed Watts qualify as high efficacy lighting.

Benefits

Requiring high efficacy lighting in residential baths will reduce energy use, which reduces atmospheric emissions, among other environmental benefits.

Environmental Impact

This measure has a positive environmental impact, although it will be necessary to address the issue of mercury in fluorescent lighting and the tradeoff with reduced energy use. Additional discussion is provided under kitchen and utility room lighting.

Type of Change

This Standards change would be implemented as a mandatory measure, although some flexibility might be provided if the requirement is expressed as a power allowance.

Measure Availability and Cost

High efficacy lighting equipment is available at a reasonable cost from multiple manufacturers. Lighting that provides good color rendering should be installed in residential baths, which will add some cost compared to the “bottom-of-the-line” products that are often installed.

Useful Life, Persistence and Maintenance

See the discussion for kitchens and utility rooms.

Performance Verification

No performance verification is required. As with all Standards requirements, plan checking and field inspection is needed for code enforcement.

Cost Effectiveness

An approach to cost effectiveness similar to the one employed for kitchens and utility rooms will be used for residential baths. The hours of annual lighting use that is needed to justify the requirement will be calculated and compared typical lighting hours for residential baths.

Analysis Tools

This requirement would be implemented as a mandatory measure and no analysis tools would be needed for compliance calculations. For life cycle cost analysis (cost effectiveness), annual lighting energy use will be calculated by multiplying the installed lighting power times the annual hours of lighting use. MICROPAS and/or CALRES may also be used to quantify cooling benefits.

Relationship to Other Measures

This requirement uses the "high efficacy lighting" definition, and is related to the high efficacy lighting requirement for kitchens and utility rooms.

Bibliography and Other Research

See the Standards change proposals for kitchens and utility rooms.

Lighting: High Efficacy Lighting In Hotel/Motel Guest Quarters

Description

This Standards change requires that permanent luminaires in hotel/motel guest rooms be high efficacy lighting. To accommodate the needs of special rooms such as luxury suites, an exception is provided for a maximum 10% of the guest room fixtures in the building, enabling them to be incandescent. This requirement would simplify the language in §130(b), as shown below.

> ***§130 (b)***
>
> *All luminaires in hotel/motel guest rooms shall employ high efficacy source(s).*
>
> *Exception: Up to 10% of the guest room fixtures in the building need not comply.*

Benefits

This requirement makes high efficacy lighting required for all permanently installed luminaires in hotel/motel guest room spaces. The requirement of §130(b) currently requires high efficacy lighting only in kitchen and baths, and this change would extend the requirement to all lighting. The requirement would achieve considerable energy savings.

Environmental Impact

This change will increase the amount of high efficacy lighting in hotel motel buildings, therefore saving energy, which would have environmental benefits in terms of reduced emissions at power plants and more electric system reliability

Type of Change

This change would be implemented as a mandatory measure.

Measure Availability and Cost

High efficacy lighting equipment suitable for use in hotel/motel guest rooms is readily available in the market from multiple manufacturers.

Useful Life, Persistence and Maintenance

The definition of high efficacy lighting includes a restriction on the use of medium-based incandescent lamp sockets. This eliminates the main risk that the energy savings would not persist. High efficacy lighting lasts longer than the incandescent lighting it replaces.

Performance Verification

Performance verification is not needed for high efficacy lighting.

Cost Effectiveness

High efficacy lighting is cost effective in almost all instances when compared to incandescent lighting. This will be demonstrated in subsequent project tasks. An approach similar to that described for kitchen, bath and utility room lighting will be used.

Analysis Tools

This recommendation would be implemented as a mandatory measure, and no analysis tools would be needed for demonstrating compliance. Simple “Energy = Power x Time” equations will be used for most of the analysis

of cost effectiveness. The added benefit of reduced cooling load will be estimated using DOE-2 or other suitable energy simulation programs.

Relationship to Other Measures

This requirement relies on the common definition of "high efficacy lighting". The requirement is similar to that for kitchens, baths and utility rooms.

Bibliography and Other Research

See the *Standards* change proposals for kitchens, baths and utility rooms.

Lighting: Recessed Lighting

Description

This change requires that recessed luminaries located in ceilings be designed to be air tight and rated, so that insulation can be in direct contact with the housing. The lighting industry produces a class of luminaire housings called ICAT (insulation contact air tight) that meet this requirement. Furthermore, if luminaires are incandescent, they must be rated for 75 Watts or less. The following is preliminary language to be included in §150(k).

> ***§150 (k)***
>
> *Recessed luminaires installed in residences shall meet the following requirements:*
>
> *1. Shall be rated for "insulated ceiling air tight (ICAT)".*
>
> *2. If equipped with an Edison or screw base, shall have an aperture not larger than 5" and shall be rated for 75 Watts or less.*

This measure would ensure that:

1. Ordinary 6" low cost, incandescent recessed "can" lights, rated up to 150 watts ICAT, would be eliminated from the marketplace, preventing socket wattage from exceeding 75 Watts. Builders would be encouraged to employ the most energy efficient halogen PAR20 and PAR30 lamps instead of inefficient R30 and R40 lamps, reducing typical socket Watts by at least 25 Watts. Or alternatively, the contractor might employ low voltage lighting, which also employs lamps of 75 Watts or less.
    a. Most lighting installed in homes uses R lamps. The 75PAR30 produces as much effective illumination as a 6" can with a 100-120 Watt R lamp. There will be no need to add more cans.
    b. The low voltage and compact fluorescent options are viable choices for individual homeowners, architects and designers.
2. For situations demanding more light from recessed "can" lights, usually in kitchens, builders would be encouraged to employ compact fluorescent "can" lights, which tend to be more expensive on a unit basis than tungsten luminaires, but competitive to employing additional 5" tungsten can lights, once labor and wiring costs are considered.

Benefits

This requirement would reduce heat losses through residential ceilings and also reduce lighting energy. Heat loss reductions would result in lowered heating and cooling energy and may also affect the efficiency of HVAC ducts. The change will save at least 25 Watts per recessed "can" light in conventional residential lighting.

Environmental Impact

The environmental impacts of this requirement are positive, including the increased use of fluorescent lighting in residences, which can increase mercury use. However, local increases of mercury are outweighed by the benefit of reductions in air-born mercury at power plants.

Type of Change

This change would be implemented as a mandatory measure in §130 (hotel/motels) and §150 (low rise residential). The Residential and Nonresidential Manuals should be updated to explain the requirement. It would also be beneficial for the Commission to develop and disseminate a fact sheet to all electrical manufacturers and distributors, prior to implementing the measure.

Measure Availability and Cost

All major manufacturers of recessed lighting in the U.S. produce, or could easily produce, products to meet this requirement. Prices, availability, and selection of current products (e.g. Halo H5 family) are consistent with, and to some degree cost less, than the 6" family equivalents. Including trim, costs for builder-grade ICAT can lights are presently about $25 per luminaire more expensive than the non-ICAT lights.

PNNL is presently funding the development of residential-grade, compact fluorescent luminaires that meet these requirements. It is strongly believed that a reasonably-priced, ICAT dimmable downlight can be produced using offshore manufacturing to cost within $25 of the current tungsten equivalent (about $75).

Useful Life, Persistence and Maintenance

This requirement will result in lighting systems that will persist, cannot be easily circumvented, provide reasonable aesthetics and choice, generally enjoy longer lamp life than the base case, and permit dimming.

Performance Verification

There is no need for performance verification for this requirement. Typical plan checking and field inspection prior to framing will be adequate to verify compliance.

Cost Effectiveness

This requirement is cost effective and calculations will be performed in subsequent tasks to demonstrate this. For example, consider the following: Assume a home has 500 annual hours of lighting operation at $0.15 per kWh for electricity. A compact fluorescent luminaire saves at least 65 Watts, as compared to a 100-Watt R or PAR lamp typically used in the 6" can, and produces the same amount of light. The homeowner saves about $5 per year for each luminaire. If the cost premium is $25/luminaire, the simple payback is about five years.

Analysis Tools

This requirement would be implemented as a mandatory measure and no analysis tools would be needed for compliance purposes. For cost effectiveness calculations, a simple "Energy = Power x Time" relationship will be used, coupled with data on typical lighting hours in residential applications, as well as power savings between conventional luminaires and those required by this measure. The benefits of reduced heat loss through the ceiling would be quantified using MICROPAS or CALRES.

Relationship to Other Measures

This measure is related to other high efficacy requirements for residential lighting.

Bibliography and Other Research

PNNL research on recessed compact fluorescent luminaires will be consulted. Apart from this, manufacturers specification sheets will provide power and cost data.

Lighting: Exterior Lighting

Description

This requirement mandates high efficacy lighting for exterior applications in residences. The intent is to require compact fluorescent lighting for porches and other exterior applications. This measure would ensure that:

- Typical outdoor lighting equipment would either be compact fluorescent (CF), HID, or motion controlled. If not motion controlled, lighting would be high efficacy, thereby using less Watts than typical incandescent lighting. If motion controlled, lights could be tungsten, since they would be off a majority of the time.
- Tungsten lighting can still be used in the mountains where compact fluorescent lamps may have difficulty starting in extremely cold environments.

> ***§150***
>
> *Exterior lighting for residences shall employ high efficacy source(s).*
>
> *Exceptions:*
>
> *1. Exterior luminaires installed in climate zones 14 or 16.*
>
> *2. Low voltage luminaires rated 50 Watts or less.*
>
> *3. Luminaires directly controlled by a motion-sensing device.*
>
> *4. Lighting used in or around swimming pools, water features, or other locations subject to Article 680 of the 2001 California Electrical Code.*

Benefits

Exterior lighting is a significant energy end-use in California. When poorly designed, it can also contribute to light trespass and pollution. This measure will require high efficacy lighting, saving energy and realizing other environmental benefits. It is estimated that the measure will save at least 25 Watts per luminaire, with typical savings between 60-80 Watts.

Environmental Impact

Environmental impact will be positive. While there may be some minor increases in mercury related to fluorescent and other high efficacy lighting, this increase will be offset by the benefit of reductions in air-born mercury from reduced energy generation at power plants.

Type of Change

This change would be a mandatory measure in §150. It would need to be described in the Residential Manual and it would probably be beneficial for the Commission to develop and disseminate a fact sheet to all electrical manufacturers and distributors, prior to implementing the measure.

Measure Availability and Cost

Many manufacturers of residential grade outdoor lighting in the U.S. produce, or could easily produce, products to meet this measure. Prices, availability, and selection of current products are reasonable and would become even more so, if this measure passes. Products on the market now can be purchased at Home Depot, Lowes, etc.

Useful Life, Persistence and Maintenance

Lamp life will be lengthened; therefore the affected lighting will require less maintenance by the owner. The definition of high efficacy lighting prohibits line voltage, medium-based sockets.

Performance Verification

No performance verification is needed. Plan check and field inspection is easy for this requirement.

Cost Effectiveness

The cost effectiveness of this requirement will be studied in later project tasks. Complying products typically cost between $10-$20 more than comparable incandescent products.

Analysis Tools

This measure would be implemented as a mandatory measure and no analysis tools would be needed to show compliance. The cost effectiveness calculations would use simple calculations based on typical hours of exterior lighting operation, as well as the power differences between conventional incandescent sources and the high efficacy lighting required by this measure.

Relationship to Other Measures

This measure relates to other exterior lighting measures to be considered by the CEC.

Bibliography and Other Research

Public Interest Energy Research (PIER) is being conducted on exterior lighting. The research being done as part of this task will be coordinated with that effort.

Other: Application of the Standards to Alterations

Description

This measure will expand the scope of the *Standards* to cover a wider range of situations when alterations are made to the dwelling. Examples of opportunities for expanded requirements include replacement windows, HVAC, duct sealing and insulation, and other envelope changes. Different Standards mechanisms and triggering events will apply, depending on the measure.

The current *Standards* establish requirements when a building is altered. Alterations are defined as changes to a building's water-heating system, space-conditioning system, lighting system, or envelope that does not increase the conditioned floor area or volume. Mandatory requirements for certain features regulated under Subchapter 2, like insulation (§118(d)), must be met. Additional requirements identified in Subchapter 9 (§152(b)) include prescriptive requirements for fenestration, space conditioning, and water heating systems. The 2001 *Standards* added testing of refrigerant charge or a Thermostatic Expansion Valve (TXV) to the space conditioning requirements (the Residential Manual allows the use of a 12 SEER instead) on replacement air conditioning equipment. There is also an exception in the *Standards* (Note to §152(b)) that exempts replacement fenestration not completed as part of an alteration from meeting the fenestration requirements. Each of these code sections will be studied and modified as needed.

Requirements for energy efficient replacement windows represent a major opportunity for energy and demand savings. Approximately half of the windows sold in California are replacement products, indicating a significant opportunity even though many replacements are already made with high performance windows. There are several types of requirements to consider for replacement windows. The simplest would be to establish specific performance levels as a mandatory measure, which could be added to section 116 or section 152(b) and could vary by climate zone if needed. An alternative approach would be to require that replacement windows meet the prescriptive requirements found in the packages (§151(f)) or newly-added prescriptive requirements for alterations. A performance option could continue to be available for cases where alternative products are desirable. The requirement for improved glazing would be when the fenestration product (combined window frame and glass unit) is being replaced. Products being repaired would continue to be exempt. Language from the *International Energy Conservation Code*, which has replacement window requirements, may provide useful guidance for this change.

Another significant opportunity exists to improve the ductwork, either with sealing and/or insulation done in conjunction with equipment replacement. Other options include: 1) increased attic insulation or radiant barriers when roofing is replaced; 2) installation of TXVs when furnaces are replaced; 3) replacement of matching indoor units when outdoor split system air conditioner units are being replaced; 4) wall insulation when homes are re-stuccoed, or re-sided. Each of these measures will be studied for inclusion in the *Standards*.

AB 549 and AB 1574 recently were passed by the state Legislature and signed by the governor. Both of these statutes potentially affect alterations in existing buildings. AB 549 requires the CEC to conduct a study of how best to address energy savings opportunities in existing residential and nonresidential buildings and report to the state Legislature by January 1, 2004. Possible recommendations could include new legislation to expand regulatory authority over existing buildings or initiate a non-regulatory program of some kind. AB 1574, among other things, gives the CEC explicit authority to develop consumer information regarding energy efficiency opportunities in existing residences.

Benefits

California has millions of existing dwelling units, the majority of which were constructed before there were energy requirements. Every time homeowners upgrade or replace building components without bringing the components up to current standards is a lost opportunity, as the most cost effective time to upgrade existing products to energy efficient products is at the time of replacement. Situations can also exist were the original construction had an energy efficient product and the homeowner installs a less efficient product. While only a fraction of existing dwellings are altered every year and many have already had some energy upgrades, the potential energy and demand savings overtime would be very large.

Environmental Impact

Significant energy, and therefore pollution savings, will occur with increased standards for alterations.

Type of Change

The proposed changes would be accomplished with a combination of modifications to Subchapter 2, the mandatory measures, and the prescriptive requirements. Changes would be documented in the *Standards* themselves, the Residential Manual, and alteration compliance forms. ACM Rules for Existing plus Alterations should also be reviewed for consistency with any changes.

A major effort will be required to make sure that everyone affected by a new alteration requirements is informed, including homeowners, builders, remodelers, contractors, building officials, vendors, retailers, and others.

Measure Availability and Cost

The alterations affected by this proposal will likely mimic the features required for new construction, so the required products will either be widely available when implemented, or can be reasonably provided by product manufacturers when the demand for the product is clear. The measure costs will likely be higher than new construction in most cases where installation is more difficult or economies of scale apply. There are also likely to be problems with upgrades to some components, such as the need to match the appearance of existing windows. Adaptation problems may also arise for some small businesses who specialize in the replacement market.

One significant issue affecting the impact of requirements for alterations is the common practice for many alterations to be done without building permits. The scope section of the *Standards* currently says that they apply to construction "for which an application for a building permit or renewal of an existing permit is filed or required by law to be filed." The *California Building Code,* Volume 1, Section 106 specifies when a building permit is required.

Useful Life, Persistence and Maintenance

The life of the component installed as a result of new requirements would likely not be different than the life of the product that the homeowner would have installed without the influence of the Standard.

Performance Verification

Some potential measures, like duct sealing or refrigerant charge and airflow, would require verification if treated the same as their new construction counterparts.

Cost Effectiveness

Establishing the baseline for life cycle costing will require a significant effort, as there is more diversity in existing construction characteristics than in new construction. For example, the benefits of adding ceiling insulation depend on the amount of existing insulation. As a result, it will be necessary to study the benefits of upgrading from several different levels, like R0, R11, and R19. For many upgrades, like replacement windows where the homeowner is already opting for an energy efficient product, only the added cost of the more efficient product may need to be considered. Some features that are inexpensive in new construction, such as duct sealing, may not be as cost effective in alterations where labor costs may be higher and the performance improvements may be less because of the difficulty of sealing existing ducts.

Analysis Tools

The analysis of measuring energy savings for new homes will be adapted for use in this effort.

Relationship to Other Measures

N/A

Bibliography and Other Research

Cardinal Glass Industries provided written documentation about replacement windows for the October 22, 2001 workshop and during the AB 970 proceedings.

Other: Residential Computer Modeling

Description

In addition to computer modeling changes that are part of other proposed measures, there are a number of refinements that will be considered for the 2005 *Standards*:

1. Slab edge. Consider calculating heat exchange using the average outdoor temperature for the previous week to more accurately calculate the impact of slab edges on the building loads.
2. Natural Ventilation. Consider modifying the operation of windows to better reflect occupant behavior with the opening/closing of windows once or twice in the evening and once or twice in the morning. The current modeling makes decisions every hour to open windows for ventilation, regardless of the time of day or the need for secure ventilation.
3. Dust Factor. Study the current dust factor used in fenestration solar gain calculations to determine if it needs to be recalibrated to adjust for other modeling changes. The dust factor scales the solar gain on windows to better account for dust and measured data that indicates that there is less solar heat gain in buildings than the calculated estimates.
4. Cool Roofs. Consider modifying the cool roof model to account for changes in the solar absorptivity based on the color of the roof and issues related to ventilation in the attic. Consider limiting the absorptivities allowed for compliance to a few key values discounted from tested values.
5. Basement Modeling. Refine the basement modeling procedure added in 1998 *Standards*. Consider calculating heat exchange using the average outdoor temperature for the past week.

Benefits

The proposed modeling changes will improve the accuracy of the compliance calculations, resolve compliance implementation issues, and help to properly value the demand and energy savings of energy efficiency features.

Environmental Impact

N/A

Type of Change

These changes would primarily be documented in the *ACM Manual*, with some minor changes to the *Residential Manual* as well.

Measure Availability and Cost

N/A

Useful Life, Persistence and Maintenance

N/A

Performance Verification

N/A

Cost Effectiveness

As these are modeling issues, there is no cost directly associated with these measures. However, these modeling changes can affect the cost effectiveness of all dwelling energy efficiency measures, as the estimates of energy use will change.

Analysis Tools

The modeling details in computer performance calculations affects all aspects of the *Standards'* development process. The best process would be to incorporate proposed changes into the computer performance method early in the process, so that the revised calculations can be used to establish the prescriptive packages based on their cost effectiveness. Eventually, all approved software will have to be modified to accommodate these proposed changes.

Relationship to Other Measures

To the extent that making these changes will modify the mix of heating and cooling energy, it will have an impact on the value of compliance measures. For example, changing the natural ventilation model will likely decrease the amount of cooling attributed to ventilation. This will increase the amount of mechanical cooling needed, making measures like low solar gain glass and higher air conditioner efficiency more attractive compliance features.

Bibliography and Other Research

Most of the changes proposed here are related to features contained in the current *ACM Manual*. Previous *Standards* and references such as the *ASHRAE Handbook of Fundamentals* will be used as needed.

NONRESIDENTIAL

Envelope: T-Bar Ceilings

Description

This measure prohibits the installation of "lay-in" insulation on top of removable ceiling tiles. Insulation that is counted towards calculating the overall thermal resistance of the roof must be at the roof deck, unless the ceiling is permanent (i.e., does not have readily removable tiles) and forms an air barrier. The walls above the ceiling tiles will be walls of the conditioned space and will be required to be insulated.

Benefits

This measure will reduce heat transfer from the outside to the conditioned space due to increased effective R-value of the insulated roof and sidewalls above the T-bar ceiling and decreased infiltration. Placing the thermal insulation at the roof deck instead of the ceiling plane will also increase the effective duct efficiency. Since the ducts will now lie within the thermal envelope, duct losses will help condition the space. Also, the duct temperature will be closer to the temperature of an insulated plenum than that of an attic space over a lay-in insulated ceiling as a result of this measure – reducing non-leakage losses into the plenum. This will further decrease heating and cooling energy consumption and the peak electrical demand needed to cool the building during the hottest times of year.

Moreover, most acoustic tile manufacturers do not recommend the use of insulation on top of these tiles because the additional weight can result in the tiles bowing over time. This is especially true if the insulation has to be compressed between the tile and building services in the plenum space.

Environmental Impact

In addition to the environmental benefits that flow from a reduction in energy consumption, limiting the use of lay-in insulation reduces the exposure to fiberglass fibers. Inhaling fiberglass can cause lung damage and other respiratory disorders, but this risk can be mitigated with encased batts. There are two scenarios for reduced exposure to fiberglass:

1. Exposure of maintenance personnel when replacing or repairing equipment in the ceiling plenum. Greater exposure to fiberglass fibers is encountered when insulation is draped over the ceiling than when the insulation is attached to the underside of the deck or insulation above the deck.
2. Potential exposure of the occupants when the HVAC system is retrofitted to a plenum return system or a plenum return system is added. Although exposed insulation in plenum return systems is in violation of code, some of these systems may get still get installed and the fiberglass fibers could then circulate into the conditioned space of the building through the HVAC unit.

Type of Change

The proposal for lay-in insulation would disallow insulation over ceilings other than continuous ceilings that cannot be readily removed. This would be a mandatory measure.

This measure would affect the nonresidential section of the *Standards* and the Nonresidential Manual. These current *Standards* will revert to the language and descriptions similar to the 1992 Title 24 Standards.

This measure does not impact the performance method and thus does not affect the computer programs or the ACM Manual.

Measure Availability and Cost

Insulating the underside of the roof deck or insulating between the roof deck and the roofing material is the typical method of insulating roofs in nonresidential buildings. Two recent building research programs in California have found that lay-in insulation is used approximately 5-10% of the time[1]. Thus the alternatives to lay-in insulation are readily available and commonly used.

Useful Life, Persistence and Maintenance

Insulation placed above or below the roof deck has more persistence than lay-in insulation. Building researchers are finding that typically all recessed troffers are uninsulated, creating large gaps in the lay-in insulation. Further gaps in lay-in insulation may occur because of the presence of interfering equipment in the plenum. Often, repair or maintenance personnel may toss aside some lay-in insulation to gain access to the plenum. This too results in patchy insulation, considerably lowering the effective R-value. Thus, lay-in insulation has less persistence than under deck insulation.

Performance Verification

Verification of insulation being installed is no different from what is currently required for most nonresidential buildings.

Cost Effectiveness

The measure is likely to be cost effective in most buildings. The prohibition against lay-in insulation will not be cost effective in buildings where the plenum space is exceptionally high. In these cases, the effective UA of the building may actually increase because the impact of the increased surface area within the thermal boundary may offset the positive impact of the lowered effective U-factor of the new insulation. The analysis will examine the significance of additional losses that may result from air leakage through the tiles, ventilation of the attic, or conduction losses through HVAC ducts. If these appear significant, the analysis will account for these effects in determining the appropriate insulation alternatives to be in the standards.

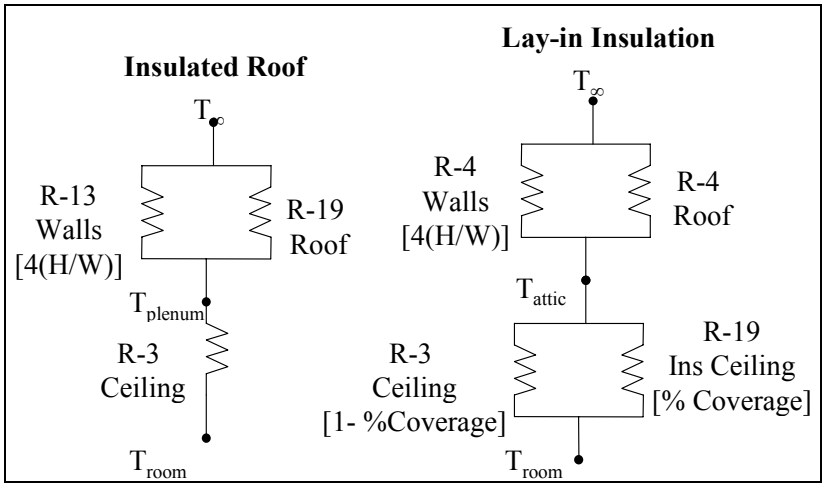


Figure 1: Thermal Network of an Insulated Roof vs. lay-in Insulation

Figure 1 illustrates the thermal networks used to evaluate the effective thermal resistance of a buildings with (1) insulated walls and roof deck and (2) lay-in insulation over the ceiling with various degrees of coverage. Note that this thermal network does not consider air leakage through the tiles, ventilation of the attic, or conduction losses through HVAC ducts. All of these factors would reduce the effective resistance of the lay-in insulation

[1] Results of a phone interviews with 200 commercial building managers for the PIER Integrated Design of Commercial Building Ceiling Systems project and from 40 on site surveys of commercial buildings for the PIER Integrated design of Small Commercial HVAC project.

more than that of the insulated roof deck. Thus this analysis is very conservative and underestimates the savings from insulating the roof deck.

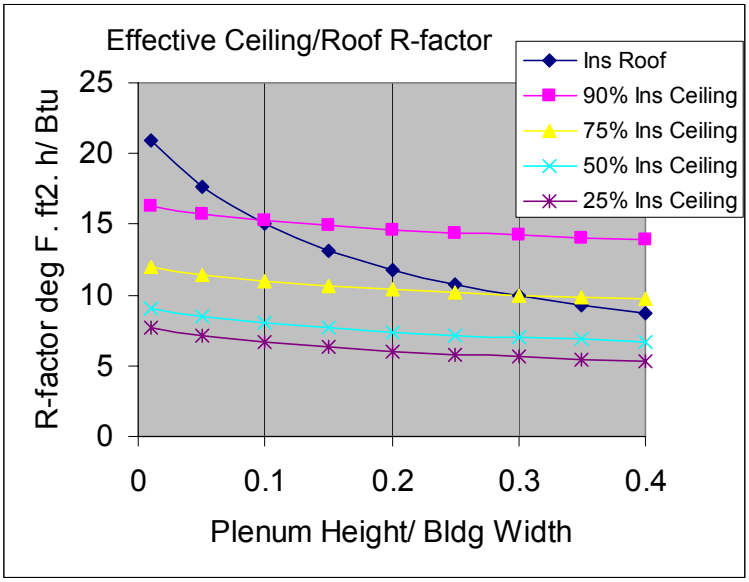


Figure 2: Effective R-values of Ceiling/Roofs for Different Plenum Heights and for different coverage of lay-in insulation

Lay-in insulation performs poorly for many building configurations and insulation coverages. Figure 2 plots the effective R-factor of these two competing methods of roof insulation. This analysis was done for buildings with a square shaped plan (building length = building width), and a flat roof. As the plenum height gets larger for a given building one would move to the left on the x-axis. Thus a square building with dimensions of 60 feet per side with an 18-foot tall plenum (0.3 plenum height /width) with an insulated roof deck would have the same effective roof/ceiling R-value of the same building containing lay-in insulation that covered 75% of the ceiling. For the same building with lower plenum heights the insulated roof would perform better than lay-in insulation with 75% coverage. Note that the largest coverage shown for lay-in insulation is 90% - this corresponds to 4 ft x 2 ft troffers on 8 ft x 10 ft spacing (the troffer space being uninsulated). Lower coverage values result from some additional tiles being uncovered.

Analysis Tools

DOE-2 is the likely simulation tool for estimating energy savings, peak demand reductions, and the TDV energy benefits that result from changes in insulation position. We will be reviewing the appropriateness of using the spreadsheet used by Mark Modera to evaluate the benefits of duct sealing. If this allows us to model the effects of lay-in insulation with sufficient reliability, we may use this approach.

Relationship to Other Measures

This measure significantly impacts the savings from sealing and insulating HVAC ducts. For many rooftop units most of the sealing and conduction losses occur in the area between the roof deck and the ceiling. If these losses occur within the thermal boundary of the building (when the roof deck and plenum walls are insulated) then these losses will contribute to the conditioning of the building.

Bibliography and Other Research

The PIER Integrated Design of Commercial Building Ceiling Systems has initiated research into this issue. This project has established an advisory group that includes representatives of the insulation and T-bar ceiling industries. In addition, this project has interviewed building managers of 200 randomly selected commercial buildings in California. Jon McHugh at HMG is the element lead for this project.

Mark Modera, at LBNL and Carrier, who has been researching duct sealing for several years, has been involved with the research for this measure. His model of energy savings from duct sealing is impacted by the placement of the thermal boundary. His model will be reveiwed to determine its potential use for this project.

Architectural Energy Corp, who are leading a PIER small rooftop efficiency project, have also been contacted. Discussions with Peter Jacobs of AEC have determined that moving the insulation to the roof deck will substantially reduce the energy losses from ducts.

HVAC: Air Side Economizers

Description

This measure would revise the threshold system size for which an air-side economizer is required, taking the climate into consideration. Currently, Title 24 requires an air-side economizer on any system above a certain size, regardless of where it is located. In climate zones with hot daytime temperatures and very cold nights (e.g. Barstow), an air-side economizer is rarely useful and therefore not cost effective. Similarly, in milder climates, air-side economizers may be cost effective for a given system, but are not required because the system falls under the size threshold.

Also, this measure would incorporate economizer damper leakage requirements from ASHRAE/IES Standard 90.1-2001 into Title 24. These requirements are as follows:

6.3.1.1.4 Dampers. *Both return air and outside air dampers shall meet the requirements of 6.2.3.3.4.*

6.2.3.3.4 Dampers. *Where outdoor air supply and exhaust air dampers are required by Section 6.2.3.2.3, they shall have a maximum leakage rate when tested in accordance with AMCA Standard 500 as indicated in Table 6.2.3.3.4.*

TABLE 6.2.3.3.4 - Maximum Damper Leakage

Climate	Maximum Damper Leakage at 1.0 in w.g.cfm per ft^2	
	Motorized	Non-motorized
HDD65>7200 or CDD50>7200	4	Not allowed
HDD65<2701 and CDD50<3601	20	20[a]
All others	10	20[a]
Notes:		

Benefits

The benefit of this measure is reduced energy consumption achieved by geographically shifting the installed base of air-side economizers to locations where they will be more frequently used.

Leakage testing helps to ensure the energy efficiency of the damper. An economizer employs dampers to deliberately separate air streams of different temperatures. When the damper leaks, the temperature difference, and therefore the energy benefit, is reduced.

Environmental Impact

The change has a positive environmental impact by reducing energy use, increasing the use of air-side economizers in climates where they are cost effective, and reducing the use of air-side economizers in climates where they are ineffective.

Type of Change

The proposed change is a modification of an existing prescriptive requirement. Section 144 E1 would be modified with a table that presents minimum system size for requiring an air-side economizers by climate.

This measure will require changes in the Compliance Forms, ECM and ACM Manual.

Measure Availability and Cost

Prefabricated air-side economizers for small units are primarily manufactured by CanFab and Micrometal. For large units, economizers are built from components by the major air-handling unit manufacturers. The baseline condition is that air-side economizers are required for systems above a certain size regardless of climate. For life cycle cost analysis, the measure will be compared to the current *Standards*.

In general terms, air-side economizers for five to 10 ton units cost roughly $900-$1,200, not including the cost of installation.

Useful Life, Persistence and Maintenance

Air-side economizers are notorious for failures in the field. No existing standards[BA69] for economizer performance or construction can be applied to improve reliability. Nonetheless, if we assume that the failure rates are evenly distributed across all economizers in California, this measure still represents an improvement.

Table 1 – Effect of Failure Modes

	Failure Mode "Open"	Failure Mode "Closed"
Hot Climate	**Bad.** Hot air is introduced into the system and unnecessary cooling energy is wasted	Not too bad. Benefit of economizer goes away but this is a small loss due to the few hours of operation.
Mild Climate	Not too bad. Warm air may be introduced on an infrequent basis	Significant loss of free cooling, the benefit of the economizer goes away

Table 1 shows the effects of the two failure modes - "open" and "closed" - in two climate types, hot and mild. The penalty of failure "open" in a hot climate is dramatic, while the penalty of failure in other climates is not so bad. The proposed measure reduces or eliminates air-side economizers in hot climates where the failure penalties are big, and increases usage in mild climates where economizer benefit is large but failure penalty (loss of free cooling) is small. As noted in the table, a significant loss of free-cooling occurs when an economizer fails shut in a mild climate.

Performance Verification

Costs will be added to the measure for performance verification. Specification performance verification is part of a New Buildings Institute PIER project. Persistence of energy savings will likely be affected by failure rates, even when performance verification has occurred.

Cost Effectiveness

The measure will be shown to be cost effective through life cycle cost analysis. Cost data will be collected for economizers of various sizes. Simulations on packaged single units with and without economizers will be performed for different climates. The simulation results (energy cost savings) will be scaled to the tonnage (size) of the unit.

Damper leakage will be assessed as follows: Both the minimum and maximum positions in the air-side economizer model will be varied to simulate leakage at both fully open and minimum position conditions. A model of energy cost penalty as a function of the amount damper leakage will be developed. The costs of the damper measures required to meet the proscribed leakage levels will be collected, and then it will be determined if this measure is life-cycle cost effective.

Analysis Tools

Building simulations and life cycle cost analysis will determine the system size breakpoints for each climate.

Relationship to Other Measures

The trade-off table for air-side economizers may need to be regenerated. The ACM Manual will need to be changed.

Bibliography and Other Research

ASHRAE 90.1 incorporates a table similar to the one proposed in this measure, but it is not adjusted for California climates.

Johnson, J and Potter, A. Method of Verifying Performance into California's Nonresidential Energy Standards: Opportunities and Obstacles, National Conference on Building Commissioning, May 2001, PECI, Inc.

HVAC: Hydronic System Measures

Description

This proposed change adopts hydronic system measures based on ASHRAE/IES Standard 90.1-2001, §6.3.4, including:

Design for variable flow (variable speed drives),

Pump isolation,

Chilled- and hot-water reset,

Isolation valves for water-loop heat pumps and miscellaneous water-cooled equipment.

The current ASHRAE/IES Standard 90.1-2001 requirements are as follows:

> ***6.3.4 Hydronic System Design and Control.*** *HVAC hydronic systems having a total pump system power exceeding 10 hp shall meet provisions of 6.3.4.1 through 6.3.4.4.*
>
> ***6.3.4.1 Hydronic Variable Flow Systems.*** *HVAC pumping systems that include control valves designed to modulate or step open and close as a function of load shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to 50% or less of the design flow rate. Individual pumps serving variable flow systems having a pump head exceeding 100 ft and motor exceeding 50 hp shall have controls and/or devices (such as variable speed control) that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow. The controls or devices shall be controlled as a function of desired flow or to maintain a minimum required differential pressure. Differential pressure shall be measured at or near the most remote heat exchanger or the heat exchanger requiring the greatest differential pressure.*
>
> *Exceptions to 6.3.4.1:*
>
> *(a) Systems where the minimum flow is less than the minimum flow required by the equipment manufacturer for the proper operation of equipment served by the system, such as chillers, and where total pump system power is 75 hp or less.*
>
> *(b) Systems that include no more than three control valves.*
>
> ***6.3.4.2 Pump Isolation.*** *When a chilled water plant includes more than one chiller, provisions shall be made so that the flow in the chiller plant can be automatically reduced, correspondingly, when a chiller is shut down. Chillers referred to in this section, piped in series for the purpose of increased temperature differential, shall be considered as one chiller.*
>
> *When a boiler plant includes more than one boiler, provisions shall be made so that the flow in the boiler plant can be automatically reduced, correspondingly, when a boiler is shut down.*
>
> ***6.3.4.3 Chilled and Hot Water Temperature Reset Controls.*** *Chilled and hot water systems with a design capacity exceeding 300,000 Btu/h supplying chilled or heated water (or both) to comfort conditioning systems shall include controls that automatically reset supply water temperatures by representative building loads (including return water temperature) or by outside air temperature.*
>
> *Exceptions to 6.3.4.3:*
>
> *(a) Where the supply temperature reset controls cannot be implemented without causing improper operation of heating, cooling, humidifying, or dehumidifying systems.*
>
> *(b) Hydronic systems, such as those required by 6.3.4.1, that use variable flow to reduce pumping energy.*
>
> *6.3.4.4 Hydronic (Water Loop) Heat Pump Systems. Each hydronic heat pump shall have a two-position automatic valve interlocked to shut off water flow when the compressor is off.*"

This measure would expand the requirements in 6.3.4.4 to include miscellaneous water-cooled equipment that is tied to a building's condenser water system, such as equipment specifically for cooling a computer room.

Benefits

These measures would primarily save energy while having minimal impact on demand. It is unknown what the effect of TDV would be on the stringency of these measures.

Environmental Impact

These measures provide energy savings with no impact on water usage or indoor air quality.

Type of Change

These changes would be new prescriptive requirements, and also involve changes in the ACM and ECM Manuals.

Measure Availability and Cost

These measures deal with equipment and controls that are readily available in the marketplace. Variable speed drives cost approximately $250/hp installed. Pressure sensors for variable flow control of pumps have an estimated cost of $1,500 per system, and 2-Position valves cost about$600 installed.

These costs will be refined if this measure meets the initial screening criteria.

Useful Life, Persistence and Maintenance

These measures are expected to have reliable performance throughout their lives. Aside from periodic recalibration of control sensors, these measures require little or no maintenance. Variable speed drives and control components should last approximately15 years.

Performance Verification

During startup, the controls contractor should verify the control systems in these measures (variable speed drives and temperature reset controls).

Cost Effectiveness

ASHRAE/IES Standard 90.1-1999 adopted these measures using lower energy costs than Title 24. A simple life-cycle cost analysis will be completed to determine if this measure should be adopted in the *Standards*. For the variable speed drives and the automatic 2-position isolation valves, DOE 2 simulations and a life-cycle cost analysis will be completed using the current CEC economic criteria. These measures largely represent off-peak savings. It is unclear what the impact of TDV would have on their stringency.

Analysis Tools

As described in the section above, DOE-2 simulation will be used.

Relationship to Other Measures

N/A.

Bibliography and Other Research

ASHRAE/IES Standard 90.1-2001.

HVAC: Duct Sealing

Description

This measure proposes the incorporation of duct sealing and leakage test requirements in ASHRAEIES Standard 90.1-2001 (§6.2.4.2) in the *Standards* §124. The leakage test requirement threshold of 3" w.c. will be reviewed to incorporate recent PIER researchThe current ASHRAE/IES Standard 90.1-2001 requirements read as follows:

> ***6.2.4.2 Ducts and Plenum Leakage***
>
> ***6.2.4.2.1 Duct Sealing****. Ductwork and plenums shall be sealed in accordance with Table 6.2.4.3A (Table 6.2.4.3B provides definitions of seal levels), as required to meet the requirements of 6.2.4.4, and with standard industry practice (see Appendix E).*
>
> ***6.2.4.2.2 Duct Leakage Tests****. Ductwork that is designed to operate at static pressures in excess of 3 in. w.c. shall be leak tested according to industry-accepted test procedures (see Appendix E). Representative sections totaling no less than 25% of the total installed duct area for the designated pressure class shall be tested. Duct systems with pressure ratings in excess of 3 in. w.c. shall be identified on the drawings. The maximum permitted duct leakage shall be:*
>
> $$L_{\max} = C_L \times P^{0.65}$$
>
> *where*
>
> *L_{max} = maximum permitted leakage in cfm/100 ft 2duct surface area*
>
> *C_L = duct leakage class, cfm/100 ft 2 at 1 in. w.c.*
>
> *6 for rectangular sheetmetal, rectangular fibrous ducts, and round flexible ducts*
>
> *3 for round/flat oval sheetmetal or fibrous glass ducts*
>
> *P = test pressure, which shall be equal to the designduct pressure class rating in inches w.c.*

Benefits

This measure will reduce energy and demand by decreasing the amount of conditioned air leaked to plenums and unconditioned spaces. It reduces fan energy as well. TDV is likely to increase the stringency of the requirements. The measure will be cost effective at lower duct pressure classes.**Environmental Impact**

This measure is not expected to have negative environmental impacts. It will reduce electricity, fuel, and gas usage, as well as electrical demand. It will increase the application of adhesives, gaskets, tape mastic, and other CEC approved duct sealants.

Type of Change

The proposed measure would add requirements to mandatory §124.

Measure Availability and Cost

This measure uses well-established products and manufacturing techniques. It applies SMACNA standards that are widely accepted by the industry.

Useful Life, Persistence and Maintenance

There are no significant persistence or maintenance issues related to this measure.

Performance Verification

This measure includes a performance test for duct systems. Typically, a ”test and balance” (TAB) contractor will perform this test. The current requirement is set for duct systems operating at 3” w.c. and higher. This threshold may be dropped through subsequent analysis and consideration of current research.

The duct leakage tests reference the SMACNA Duct Leakage Test Procedures (1985). These are tests performed by TAB contractors during project startup.

Cost Effectiveness

The ASHRAE/IES Standard 90.1 Committee adopted this measure as part of the 1999 Standard. The economic criteria for the 90.1 Standard is less stringent, with lower present value energy cost and higher discount rate, than that used by Title 24 *Standards*.

The threshold for the duct leakage tests will be examined through life-cycle cost analysis. The energy savings will be developed either from simulation or field measurements from research. The costs will come from TAB contractor cost estimates.

Analysis Tools

N/A.

Relationship to Other Measures

N/A.

Bibliography and Other Research

SMACNA Duct Leakage Test Procedures. “HVAC Air Duct Leakage Test Manual,”1985.

LBNL PIER Research, http://buildings.lbl.gov/CEC, http://buildings.lbl.gov/CEC/project4-lec/frame_lec.html

HVAC: ACM HVAC System Map and Default Systems' Parameter Update

Description

This proposal would update the Alternate Calculation Manual (ACM) HVAC system map and default systems' parameters drawing from the ASHRAE Standard 90.1-2001 Energy Cost Budget Method. The system map defines the standard system utilized in the performance method. It generates the standard system using the occupancy of the proposed project and the building size. ASHRAE takes the category of proposed HVAC equipment as the basis for the standard system. Both will be reviewed as part of this study. The systems' parameters are the control set points that are always used in the modeling of the standard system and are the default set points for the proposed system.

Benefits

The HVAC system map and default systems' parameters for the ASHRAE Standard 90.1-2001 were developed the last four years, and are more consistent with standard design practice. The HVAC system map and default systems' parameters in the current ACM Manual were developed six to eight years ago. This measure aims to improve the baseline model utilized in the performance method.

This method's impact on the stringency of the *Standards* is unknown. It will provide a more accurate baseline by representing current design practice.

Environmental Impact

The environmental impact of this measure is unknown.

Type of Change

This measure will modify the tradeoff methodology used in the standard's performance method. It will only require a change in the ACM Manual.

Measure Availability and Cost

No costs are associated with this proposal.

Useful Life, Persistence and Maintenance

N/A.

Performance Verification

N/A.

Cost Effectiveness

N/A.

Analysis Tools

N/A.

Relationship to Other Measures

N/A.

Bibliography and Other Research

ASHRAE/IES Standard 90.1-2001.

HVAC: Chiller Table Modifications

Description

This measure proposes to update the reference standard for all chillers from ARI 550-1992 to ARI Standard 550/590-1998. It is expected to result in no change in the stringency of the requirements. In addition, the proposal will simplify and combine the Standard Tables 1-C8 through 1-C10 (tradeoff method for centrifugal chillers) by reducing each table to two or three discrete alternative rating points per chiller size category (see the example below). These rating points will be selected from the existing tables to represent a range of chiller operating conditions. The selected rating points will be adjusted to represent selections based on ARI's Standard 550/590-1998.

The proposal will replace Tables 1-C8 through 1-C10 with a single table for water-cooled centrifugal chillers that cannot operate stably at ARI 550/590-1998 test conditions. This proposed table will look like the following example:

Size Category	Alternate rating condition[1]	COP	NPLV
≤15O Tons	Rating condition 1	X1	Y1
	Rating condition 2	X2	Y2
	Rating condition 3	X3	Y3
>150 tons ≤ 300 tons	Rating condition 1	X4	Y4
	Rating condition 2	X5	Y5
	Rating condition 3	X6	Y6
> 300 tons	Rating condition 1	X7	Y7
	Rating condition 2	X8	Y8
	Rating condition 3	X9	Y9

[1]: Rating conditions are defined as specific chilled water supply temperature, chilled water flow (gpm/ton), condenser water supply and condenser water return using ARI Standard 550/590-1998.

A procedure will be developed to map COP and IPLV from the 1992 versions of the ARI Standards to the 1998 version of the *Standard* (COP and NPLV). The COP will be adjusted to account for changes in the fouling factors between the two versions of the *Standards*[2]. The ARI Standards provide equations that relate fouling factors to the leaving chilled water temperature. In turn changes in leaving chilled water temperature can be used to modify COP values using equations in the present versions of Tables 1-C8 through 1-C10. These two sets of equations can be combined to adjust the COP in Tables 1-C8 through 1-C10 on a like-for-like basis between the two versions of the ARI Standard.

The conversion of IPLV in the 1992 *Standard* to NPLV in the 1998 *Standard* will be more difficult. Both the condenser relief curves and weighting factors for the IPLV and NPLV calculations have changed between the 1992 and 1998 versions of the *Standards*. A technique to translate between these two sets of weighting factors and condenser relief curves will be developed. A curve will be taken from either the CoolTools library of chiller curves or from the default curves in the present ACM Manual to use as a basis for the conversion. The curve can be scaled to the rated COP and subsequently queried for its efficiency at the three additional rating points (75%, 50% and 25% load). These additional rating points will be selected as specified in the 1998

[2] The 1998 version of the Standard reduced the fouling factors used in calculation of the rated efficiency. For a given chiller this change would make the chiller COP higher in the 1998 version of the Standard than the COP when rated to the 1992 version of the Standard.

ARI Standard and will be combined into an NPLV for the table using the procedure in the 1998 *Standard*. The project will consult with ARI to develop these changes. .

Benefits

Several reasons exist to pursue this measure, including:

1. Design professionals, contractors, and owners are using the 1998 version of ARI's Standard to specify chiller performance. This proposed update will reduce confusion for the specifiers of this equipment since they will only have to receive ratings using one version of the *Standard*.
2. The proposed changes to Tables 1-C8 through 1-C10 will improve enforceability of the *Standard* by reducing the number of potential rating conditions for centrifugal chillers. As it stands today, an infinite number of possible rating conditions exist for centrifugal chillers that are not designed for operation at the ARI Standard test condition. The proposed change reduces this number to only three or four alternate rating conditions.
3. This measure will reduce the amount of pages in the *Standards* by combining three full-page tables into a simple half-page table.

Environmental Impact

Not applicable. This measure does not change the stringency of the *Standards*.

Type of Change

This measure changes an existing mandatory measure. Changes will be made to section 112 and Tables 1-C8 through 1-C10 of the *Standards*.

Measure Availability and Cost

Not applicable. This measure does not change the stringency of the *Standards*.

Useful Life, Persistence and Maintenance

Not applicable. This measure does not change the stringency of the *Standards*.

Performance Verification

Not applicable. This measure does not change the stringency of the *Standards*.

Cost Effectiveness

Not applicable. This measure does not change the stringency of the *Standards*.

Analysis Tools

The existing equations in Tables 1-C8 through 1-C10 will be applied in combination with equations in ARI Standard 550/590, which will adjust the efficiencies to reflect the changes in fouling factors between the 1992 and 1998 versions of the ARI Standards.

Relationship to Other Measures

Not applicable. This measure does not change the stringency of the *Standards*.

Bibliography and Other Research

Karim Amrane, ARI's representative on the ASHRAE/IES Standard 90.1 committee.

ARI Standard 550-1992.

ARI Standard 590-1992.

ARI Standard 550/590-1998.

The CoolTools Project.

HVAC: Duct and Pipe Insulation

Description

This proposed measure would add a duct insulation section in the *Standards*, rather than just a reference to the CMC. The measure would also update both the duct and pipe insulation requirements to consider increases in R-value that are shown to be cost effective through life cycle cost analysis.

As a basis of the new section on duct insulation, this proposal would consider language and format from both Section 604 of the CMC and ASHRAE/IES Standard 90.1-2001. The ASHRAE/IES Standard 90.1-2001 section on duct insulation reads as follows:

> *"**6.2.4.1.2 Duct and Plenum Insulation.** All supply and return ducts and plenums installed as part of an HVAC air distribution system shall be thermally insulated in accordance with Tables 6.2.4.2A and 6.2.4.2B.*
>
> ***Exceptions to 6.2.4.1.**2:*
>
> *(a) Factory-installed plenums, casings, or ductwork furnished as a part of HVAC equipment tested and rated in accordance with 6.2.1.*
>
> *(b) Ducts or plenums located in heated spaces, semi-heated spaces, or cooled spaces.*
>
> *(c) For runouts less than 10 ft in length to air terminals or air outlets, the rated R-value of insulation need not exceed R-3.5.*
>
> *(d) Backs of air outlets and outlet plenums exposed to unconditioned or indirectly conditioned spaces with face areas exceeding 5 ft 2 need not exceed R-2; those 5 ft 2 or smaller need not be insulated."*

The referenced tables are at the end of this document.

We propose to update both the tables from ASHRAE/IES Standard 90.1-2001 and the pipe insulation table in Title 24 (Table 1-G) using life cycle cost analysis and the current CEC economic criteria.

The CMC (§604, Table 6-D) presently has requirements for duct insulation that are expected to be different from the upgraded requirements determined to be cost effective for the 2005 *Standards*. If enough time exists, it would be desirable for the CMC levels to be changed to the same levels.

Benefits

Duct and pipe insulation reduce energy use by decreasing system distribution losses. These losses occur at all times, both on and off peak. Consideration of TDV will likely increase the stringency of these requirements.

Environmental Impact

These measures will reduce both gas and electric energy use. The revised analysis is likely to produce a more stringent standard, requiring greater amounts of insulation to be used in buildings.

Type of Change

These changes are mandatory requirements. Duct insulation is presently covered in §124 of the *Standards*, and pipe insulation is addressed in §123. No changes are necessary for either the compliance forms or ACM. Changes will be required in the Nonresidential Compliance Manual.

Measure Availability and Cost

Several major manufacturers of duct and pipe insulation exist. In such a well-developed marketplace, existing products will likely meet any new requirements.

Useful Life, Persistence and Maintenance

In the AB 970 Standard, measures for protection of pipe and duct insulation were incorporated specifically to improve the persistence of these measures. These provisions will be reviewed to insure that they cover all acceptable protection approaches. Proposed increases in the duct and pipe insulation levels are not expected to affect the persistence or maintenance of the insulation.

Performance Verification

N/A.

Cost Effectiveness

A life cycle cost study, similar to that used in the evaluation of duct and pipe insulation for ASHRAE/IES Standard 90.1-1999, will be repeated for these measures using California utility costs and current cost data for insulation products. New research on insulation costs will have to be performed.

Analysis Tools

The ASHRAE/IES Standard 90.1-1999 study was a spreadsheet analysis.

Relationship to Other Measures

N/A.

Bibliography and Other Research

ASHRAE/IES Standard 90.1-1999 and 2001.

HVAC: Packaged Single Zone VAV

Description

This proposed prescriptive measure requires variable air volume controls on the supply fans of all packaged air conditioners and heat pumps above a certain size. These controls will only be required on systems with two or more compressors. Typically, these units are seven and a half tons and larger. The requirements of this measure can be met with either 2-speed motors or variable speed drives.

Units up to 20 tons are currently covered by the Energy Policy Act of 1992 (EPACT). Research will determine if the EPACT exemption applies to these proposed controls on units 20 tons and smaller.

Benefits

This off-peak measure will provide significant energy savings. On its own, the measure will not provide demand reduction, but saves energy during part-load conditions by reducing the supply fan speed when the compressors are unloaded.

If implemented, the measure will provide a means for significant load shedding. At half-speed, the supply fan energy should drop by approximately 1/8 of the design kW, and the compressor energy will drop to approximately half of its design kW (or greater depending on the condenser circuiting).

Environmental Impact

This measure will considerably reduce energy use with no significant increase in the consumption of other resources.

Type of Change

This proposal would be a new prescriptive measure. It would require changes in the *Standards*, ACM Manual, the Nonresidential Compliance Manual, and the compliance forms.

Measure Availability and Cost

Trane and Carrier are the principal manufacturers of these products. York and McQuay also manufacture this equipment. All of these manufacturers offer variable speed drives for the supply fans as the standard option on large equipment. On all packaged equipment, the controls that vary the speed of the supply fan have to be interlocked with the controls that stage the compressors to prevent coil freezing and unacceptable supply air temperatures (draft). The best way to accomplish this is through factory-mounted controls, which are warranted by the manufacturers with the equipment. These proposed controls could also be provided through third parties in the field. However, since that may void the manufacturer's warranty on the refrigeration equipment, this issue requires more investigation.

Equipment with these variable speed supply fan controls is currently offered by the major manufacturers in the residential market and has been developed and offered in the commercial market in the past (there has been at least one product line in the five to 10-ton range developed for an ESCO). This change is not significant for the manufacturers since they are already familiar with the components and controls.

This measure's baseline for evaluation is packaged equipment with a constant speed supply fan.

Useful Life, Persistence and Maintenance

The addition of variable speed drives or 2-speed motors will add complexity to the controls, but should not cause additional wear and tear on the supply fan or refrigeration system. The life of a commercial package unit is approximately 15 years.

Performance Verification

No field verification is proposed if the factory installs the controls. If the controls are field-installed, the contractor installing the controls will provide verification during startup.

Cost Effectiveness

This measure is likely to be cost effective.

Cost premiums will be estimated using the incremental costs of the new components and controls, and energy savings will be developed through simulations. Life cycle cost analysis will be completed as a function of both climate and unit size.

Analysis Tools

Standard DOE2-based simulation tools will be used to evaluate this measure.

Relationship to Other Measures

This change should not interact with any other measure.

Bibliography and Other Research

None.

HVAC: Shutoff Dampers

Description

This proposal would modify the existing shut-off damper requirement (§122(f)) to include climate-based leakage requirements using language from ASHRAE/IES Standard 90.1-2001. The ASHRAE/IES Standard 90.1-2001 requirement for motorized dampers in the most extreme climates also will be considered.

The current Title 24 Requirement reads as follows:

> *"Dampers for Air Supply and Exhaust Equipment. Outdoor air supply and exhaust equipment shall be installed with dampers that automatically close upon fan shutdown.*
>
> *EXCEPTION 1 to Section 122 (f): Where it can be demonstrated to the satisfaction of the enforcing agency that the equipment serves an area that must operate continuously.*
>
> *EXCEPTION 2 to Section 122 (f): Gravity and other nonelectrical equipment that has readily accessible manual damper controls.*
>
> *EXCEPTION 3 to Section 122 (f): At combustion air intakes and shaft vents.*
>
> *EXCEPTION 4 to Section 122 (f): Where prohibited by other provisions of law."*

The ASHRAE/IES Standard 90.1-2001 requirement reads as follows:

> **"*6.2.3.3.4 Dampers.*** *Where outdoor air supply and exhaust air dampers are required by Section 6.2.3.2.3, they shall have a maximum leakage rate when tested in accordance with AMCA Standard 500 as indicated in Table 6.2.3.3.4.*
>
> ***TABLE 6.2.3.3.4***
>
> ***Maximum Damper Leakage***

Climate	***Maximum Damper Leakage at 1.0 in w.g.cfm per ft 2 of damper area***	
	Motorized	**Non-motorized**
HDD65>7200 or CDD50>7200	*4*	*Not allowed*
HDD65<2701 and CDD50<3601	*20*	*20[a]*
All others	*10*	*20[a]*
Notes:		
a Dampers smaller than 24 in. in either dimension may have leakage of 40 cfm/ft².		

Benefits

This measure will save fuel and electric energy, as well as electric demand through decreased infiltration.

Environmental Impact

This measure has no negative environmental impacts.

Type of Change

This proposal modifies an existing mandatory measure.

Measure Availability and Cost

Automatic dampers are widely available from a number of manufacturers. Costs will be developed under this measure's life cycle cost study.

Useful Life, Persistence and Maintenance

These dampers will last approximately 15 years and have no persistence or major maintenance issues.

Performance Verification

The controls for automatic dampers must be verified during startup, which is a normal part of the controls contractor's startup procedures.

Cost Effectiveness

This measure is likely to be cost effective. Using models, leakage will be simulated by varying the infiltration and/or economizer minimum position on HVAC units. The life cycle cost analysis will seek to answer how much leakage (in cfm/ft^2) is required to pay for each increment in leakage rating.

Evaluating the cost effectiveness of this measure will involve estimating the cost of the measure, and then determining the reduction in threshold amount of infiltration required to pay for the installation of the dampers.

Analysis Tools

Simulation programs and spreadsheet analysis will be used.

Relationship to Other Measures

N/A.

Bibliography and Other Research

None.

HVAC: Stair and Shaft Vents

Description

This proposed new mandatory measure would adopt a requirement for motorized dampers on stair and elevator shaft vents, based on the requirement presently in ASHRAE/IES Standard 90.1-2001 (§6.2.3.3.1). This requirement reads:

> *"Stair and elevator shaft vents shall be equipped with motorized dampers that are capable of being automatically closed during normal building operation and are interlocked to open as required by fire and smoke detection systems."*

Exceptions for non-motorized dampers in buildings less than three stories in height above grade, and in buildings of all sizes in climates with less than 2700 HDD65, are also proposed.

The CBC (§3004) presently states that, "*Vents shall be capable of manual operation only*." For the proposed measure to work, this limitation would need to be removed from the CBC, which would require coordination between the CEC and other state agencies, in particular the State Fire Marshall's Office

Benefits

Infiltration through stairwells and elevator shafts due to stack effect can significantly add to both heating and cooling loads in tall buildings. Motorized dampers greatly decrease this airflow. In small buildings or in mild climates, gravity dampers would be sufficient to prevent airflow resulting from stack effect.

Environmental Impact

This measure would reduce both fuel and electrical energy usage.

Type of Change

This new measure would be mandatory. It would require the application of either motorized or gravity dampers.

This requirement would produce minor changes in the Nonresidential Manual, the ECM, the *Standards*, and the compliance forms. No changes are anticipated for the ACM.

Measure Availability and Cost

Both gravity and automatic dampers are standard products that are widely available. They range in cost from several hundred dollars to several thousand, depending on the size of the vent.

The baseline is a building with no damper on these vents and increased stack-driven infiltration, due to the open vents in both the stairwells and elevator shafts.

Useful Life, Persistence and Maintenance

Gravity and automatic dampers should last 15 to 20 years. In this application, they should operate throughout their life with no need for either maintenance or repair.

Performance Verification

The action of the automatic dampers would have to be verified with the rest of the life-safety control system at startup.

Cost Effectiveness

This measure is likely to be cost effective. Performance would be evaluated by first estimating the cost of the measure, and then determining the reduction in the threshold amount of infiltration necessary to pay for the

installation of the dampers. Existing equations of stack infiltration would be applied to openings typical of stair and elevator vents in different climates and building heights. These calculated rates of infiltration would be compared to the threshold values from the life cycle cost effectiveness study.

Analysis Tools

This measure can be evaluated in a spreadsheet analysis.

Relationship to Other Measures

This measure has no relationship to other measures.

Bibliography and Other Research

ASHRAE/IES Standard 90.1-2001.

1998 California Building Code.

HVAC: VAV Fan Control Measures

Description

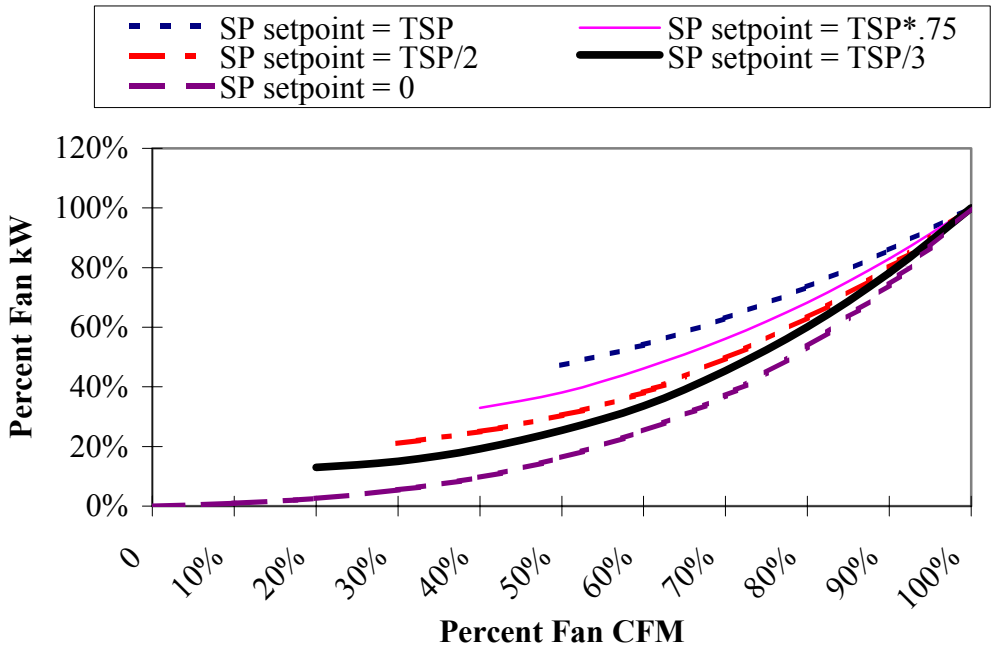
This measure proposes to adopt a new prescriptive requirement for VAV fan controls in Title 24 2005 based on §6.3.3.2 of ASHRAE/IES Standard 90.1-2001. These measures state:

> *"6.3.3.2.2 Static Pressure Sensor Location. Static pressure sensors used to control variable air volume fans shall be placed in a position such that the controller set point is no greater than one-third the total design fan static pressure, except for systems with zone reset control complying with 6.3.3.2.3. If this results in the sensor being located down-stream of major duct splits, multiple sensors shall be installed in each major branch to ensure that static pressure can be maintained in each.*
>
> *6.3.3.2.3 Set Point Reset. For systems with direct digital control of individual zone boxes reporting to the central control panel, static pressure set point shall be reset based on the zone requiring the most pressure; i.e., the set point is reset lower until one zone damper is nearly wide open."*

The 6.3.3.2.3 requirement will be changed to allow controls based on the average signal from a group of dampers (e.g. the worst 10%).

Benefits

Research has shown that fan energy usage in VAV systems is dramatically affected by placement of the pressure sensor, as illustrated in the following graphic (developed through spreadsheet analysis by Steve Taylor).



In addition to the fan energy savings realized by the lower pressure setpoint, the system turn down (minimum percentage of design cfm at which the system can stably operate) is dramatically improved. Fans will surge at low cfm and high static pressure. Surge is a stall phenomenon that causes fans to pulse, causes audible noise, and can lead to catastrophic equipment failure. With a properly reset pressure signal, the fans can ride out the system curve to the minimum operating cfm required to cool the motor attached to the variable speed drive.

This measure impacts off peak performance. The effect of TDV on this measure is unknown without further research.

Environmental Impact

This measure will reduce electrical energy with no increase in other resources.

Type of Change

This measure will add a prescriptive measure to the *Standards* (or modify existing prescriptive measure 144(c)). It requires changes in the *Standards,* the compliance forms, the Nonresidential Manual, the ECM, and the ACM.

Measure Availability and Cost

This measure utilizes control components that are already part of the design, and deals with the application of those components in practice. For VAV systems with conventional controls, it merely specifies the performance requirements for pressure sensor placement that is an integral part of the system. For VAV systems with DDC controls, it adds some minor programming to reset the signal from that pressure sensor. This measure has negligible cost.

Useful Life, Persistence and Maintenance

This measure has the same lifetime, persistence, and maintenance as the base case. Both use the same components.

Performance Verification

The operation of these controls will have to be verified during startup for both the base case and the proposed measure.

Cost Effectiveness

Since this measure saves energy at a negligible cost, it is extremely cost effective.

Analysis Tools

A simple spreadsheet analysis can demonstrate the cost-effectiveness of this measure.

Relationship to Other Measures

None.

Bibliography and Other Research

ASHRAE/IES Standard 90.1-2001.

HVAC: Size Threshold for VAV Fan Controls

Description

This measure proposes to reevaluate the cost effective break point (fan motor horsepower) for the fan controls in §144(c)2B. Presently, these controls are only required on fans with a horsepower of 25 or greater. Given the reduction in costs for variable speed drives, this threshold could be lowered through life cycle cost analysis.

Benefits

Lowering the threshold for this requirement will allow for its application on more air handling systems, which will result in greater fuel and electric energy savings. The impact of TDV is uncertain for this part load measure.

Environmental Impact

This measure will increase both fuel and electric energy savings, as well as increasing the application of variable speed drives.

Type of Change

§144(c), the existing prescriptive requirement, will be revised in this proposal. Corresponding changes to the threshold value for variable air volume curves in the ACM will be required.

Measure Availability and Cost

Variable speed drives are widely available from a number of manufacturers. They currently cost approximately $250 per horsepower installed.

Useful Life, Persistence and Maintenance

Variable speed drives, and the associated controls, should last 10 to 15 years. Once commissioned, variable speed drives rarely fail or drift in performance over their lives and do not require any maintenance.

Performance Verification

These controls will have to be verified with the rest of the control system during startup.

Cost Effectiveness

Through life cycle cost analysis using current California rates and reduced cost variable speed drives, it is believed that the threshold should drop.

In support of this measure, current cost data for variable speed drives in motor sizes between five and 25 horsepower will be collected. DOE2 simulations will be used to develop energy cost savings.

Analysis Tools

DOE2 simulations will be run to develop energy savings for the life cycle cost analysis.

Relationship to Other Measures

None anticipated.

Bibliography and Other Research

None.

HVAC: Zone Isolation Control Requirement

Description

This proposal would update the current mandatory zone isolation control requirement §122(g) based on language from ASHRAE/IES Standard 90.1-2001. The ASHRAE requirements currently state:

> *"6.2.3.2.4 Zone Isolation. HVAC systems serving zones that are intended to operate or be occupied non-simultaneously shall be divided into isolation areas. Zones may be grouped into a single isolation area provided it does not exceed 25,000 ft 2 of conditioned floor area nor include more than one floor. Each isolation area shall be equipped with isolation devices capable of automatically shutting off the supply of conditioned air and outside air to and exhaust air from the area. Each isolation area shall be controlled independently by a device meeting the requirements of 6.2.3.2.1 (Automatic Shutdown). For central systems and plants, controls and devices shall be provided to allow stable system and equipment operation for any length of time while serving only the smallest isolation area served by the system or plant.*
>
> *Exceptions to 6.2.3.2.4: Isolation devices and controls are not required for the following:*
>
> *(a) Exhaust air and outside air connections to isolation zones when the fan system to which they connect is 5000 cfm and smaller.*
>
> *(b) Exhaust airflow from a single isolation zone of less than 10% of the design airflow of the exhaust system to which it connects.*
>
> *(c) Zones intended to operate continuously or intended to be inoperative only when all other zones are inoperative."*

Note that §6.2.3.2.1 of ASHRAE/IES Standard 90.1-2001 is similar to §122(e) Shut-off and Reset Controls for Space-Conditioning Systems of Title 24. It requires timeclocks, spring wound timers, or occupant sensors for systems that serve zones not continuously occupied.

The ASHRAE language has several advantages over Title 24 §122(g):

1. Exception (c) permits spaces greater than 25,000 ft^2 where systems are operated on the same schedule (e.g. an airport terminal)..
2. The proposed language specifies that central plants shall be designed for stable control with the smallest isolation zone in operation, which will save energy as plant turndown is essential to realizing the savings from isolation zones. Without specifically requiring this, designers might overlook it.

Benefits

The benefit of the proposed language is twofold:

1. It is more clearly written and therefore more likely to be applied, and
2. It specifies new requirements for central plants that will extend the application of this measure. The current requirement is not explicit on how to use a central plant to support isolation requirements. If designers neglect the central plant, they will not get the intended turndown in the field.

Environmental Impact

It is anticipated that this measure will provide energy savings without adversely impacting the environment.

Type of Change

This change modifies an existing mandatory measure. No changes are anticipated in either the compliance forms or ACM. The ECM may need to be revised.

Measure Availability and Cost

This measure provides savings without adding cost or complexity to the HVAC system or controls.

Useful Life, Persistence and Maintenance

Both the proposed measure and baseline condition have the same useful life, persistence, and maintenance.

Performance Verification

All controls should be verified during start-up for both the proposed measure and baseline condition.

Cost Effectiveness

Since the measure provides some energy savings at no cost , it is extremely cost effective. A brief spreadsheet analysis will be provided.

Analysis Tools

A spreadsheet analysis of the savings will be completed.

Relationship to Other Measures

None identified.

Bibliography and Other Research

ASHRAE/IES Standard 90.1-2001.

Lighting: Definition of Daylit Area

Description

This change would modify the definition of the daylit area next to vertical glazing. Presently, the daylit area is defined as a 15 ft band next to the window wall. With this change, daylit area would be defined as a ratio of the distance from the floor to the top of the window. This definition is more consistent with design guidelines from the IESNA and other sources, and distinguishes between high and low windows.

§101 Change

DAYLIT AREA is the space on the floor that is the larger of 1 plus 2, or 3;

1. For areas daylit by vertical glazing, the daylit area has a depth of 2.0 times the distance from the floor to the top of the glazing ~~length of 15 feet~~, or the distance on the floor, perpendicular to the glazing, to the nearest 60-inch or higher opaque partition, whichever is less; and a width of the window plus either 2 feet on each side, the distance to an opaque partition, or one half the distance to the closest skylight or vertical glazing, whichever is least.

2. For areas daylit by horizontal glazing, the daylit area is the footprint of the skylight plus, in each of the lateral and longitudinal dimensions of the skylight, the lesser of the floor-to-ceiling height, the distance to the nearest 60-inch or higher opaque partition, or one half the horizontal distance to the edge of the closest skylight or vertical glazing.

3. The daylit area calculated using a method approved by the commission.

Benefits

In buildings with tall windows, this change will increase the number of luminaires that are subject to the daylight switching and control provisions of §131(c). Spaces with windows positioned closer to the floor would have an appropriately smaller daylit area, eliminating unnecessary daylighting controls.

Environmental Impact

There is no environmental impact apart from the positive benefit of energy savings.

Type of Change

This change would modify the requirement for daylight controls. Spaces larger than 250 ft² must have separate control of luminaires located in daylit areas.

Measure Availability and Cost

This change would only affect the local circuiting of lighting. Separate controls are already required; this change would only affect the number of luminaires to be switched. Switching controls are readily available at no significant cost.

Useful Life, Persistence and Maintenance

Same as existing standard.

Performance Verification

The separate switching requirement for daylit areas only requires manual controls. These require no performance verification.

Cost Effectiveness

This change would not add cost since it is a minor modification to an existing requirement. More accurately defining the daylit area would make switching of daylit areas more effective, saving more energy. If more energy is saved without adding cost, then cost effectiveness is improved.

Analysis Tools

There are a number of analysis tools available for calculating lighting levels in spaces and determining the depth of daylighting into a space, including LumenMicro, Radiance, and LightScape. However, such tools are not needed to implement this change.

Relationship to Other Measures

This definition should be considered in the context of proposed daylighting controls revisions (see below).

Bibliography and Other Research

The *IESNA Handbook* and other texts on daylighting will provide information on the effective daylighting area next to windows.

Lighting: Electronic Ballasts

Description

This change would require electronic ballasts to the extent not pre-empted by Federal law. This measure would effectively eliminate magnetic ballasts from the new construction market. It is expected that electronic ballasts would become standard practice, displacing magnetic ballasts even in the replacement market.

Benefits

More reliable and effective products would be provided to consumers. This requirement may also result in energy savings, emission reductions, and other benefits. Electronic ballasts will reduce operating power by 20% when compared to magnetic ballasts.

Environmental Impact

There are no negative environmental impacts associated with this measure.

Type of Change

This would be a mandatory measure in §132. The Nonresidential and Residential Manuals would need to be updated. As with other lighting measures, it would be beneficial for the Commission to develop and disseminate a fact sheet to all electrical manufacturers and distributors, prior to implementing the measure. This requirement is consistent with upcoming federal regulations being considered.

Measure Availability and Cost

The electronic high frequency ballast has become the standard practice of the lighting industry, being installed in over 60% of the new lighting equipment in the U.S. today. The current §132 language is dated.

Useful Life, Persistence and Maintenance

This measure has no specific effect on the life, persistence, and maintenance of lighting by the owner. Some electronic ballasts can even improve lamp life. The power savings and benefits of this measure are well established and have been promoted by the *Advanced Lighting Guidelines* since 1990.

Performance Verification

No performance verification is needed.

Cost Effectiveness

Electronic ballasts are cost effective, as will be demonstrated in subsequent tasks.

Analysis Tools

This change would be implemented as a mandatory measure, and no calculations are needed to show compliance. Cost effectiveness calculations can use simple power, time, and energy relationships.

Relationship to Other Measures

The lighting power allowances already assume that electronic ballasts are used in most applications. There is no connection to other measures.

Bibliography and Other Research

The veracity of this idea is supported by the *Advanced Lighting Guidelines* and other research.

Lighting: Variable Light Level

Description

This change would require bi-level illumination in more applications. Currently, there is an exception for lighting systems that have less than 0.8 W/ft². This threshold would be reduced to 0.6 W/ft². This change effectively eliminates the exception, except for warehouses and other spaces with low lighting power.

Benefits

This measure would further enable reduced light level operation throughout most buildings. This will reduce energy consumption and associated power plant emissions. In times of electricity crises, this measure will give building owners the option of reducing power significantly while continuing their operations.

Environmental Impact

There is no negative environmental impact.

Type of Change

This would be a mandatory measure in §131.

Measure Availability and Cost

The added cost for another switch is about $35 per space. Conventional switches and equipment may be used to satisfy the requirement.

Useful Life, Persistence and Maintenance

There are no useful life, persistence, or maintenance issues related to this measure. The power savings and benefits of this measure are well established and have been promoted by the *Advanced Lighting Guidelines* since 1990.

Performance Verification

There are no performance verification requirements.

Cost Effectiveness

This measure is expected to be cost effective, as will be demonstrated in subsequent research. This measure will increase the cost of construction by about $0.35 per square foot. It will permit the reduction of power by an average of 0.2 W/ft², resulting in demand savings as well as kWh savings.

Analysis Tools

This is a mandatory measure so no calculations are needed for compliance. Cost effective calculations will use simple power, time, and energy relationships.

Relationship to Other Measures

This requirement relates to other lighting control measures.

Bibliography and Other Research

Variable lighting (bi-level illumination) has been in the Standards for years. Similar requirements are absent from *ASHRAE/IESNA Standard 90.1-1999*.

Lighting: Daylighting Controls

Description

This change revises daylighting controls for large, single zone spaces. It requires automatic daylight dimming (continuous or stepped) in large spaces having daylit zones, and requires a minimum of two manual light levels and distributions in smaller spaces.

Benefits

This measure would ensure that daylighting control is installed to properly accommodate classrooms and other large daylit zones.

Environmental Impact

This measure can save up to 50% of the energy normally used in large, single daylight zone spaces.

Type of Change

This would be a mandatory measure. The Nonresidential Manual would address its application.

Measure Availability and Cost

Automatic daylighting controls are currently somewhat expensive. A classroom system presently costs between $1,000 and $2,000, including dimming ballasts. Equipment is readily available from multiple manufacturers.

Useful Life, Persistence and Maintenance

The power savings and benefits of this measure are well established and have been promoted by the *Advanced Lighting Guidelines* since 1990. The largest unknown is the calibration and performance of automatic daylight dimming systems and their associated controls.

Performance Verification

Photocell controls require careful calibration and maintenance in order to achieve lasting energy savings. This measure should be accompanied by performance verification requirements.

Cost Effectiveness

This requirement will be shown to be cost effective in subsequent tasks. This measure will increase the cost of construction by about $1.50 per square foot, on average. It will permit the reduction of power by 0.6 W/ft² on average, resulting in demand savings as well as kWh savings. The critical analysis is the relative cost of dimming ballast equipment, which will be needed to implement this requirement.

Analysis Tools

The reference method for nonresidential buildings, DOE-2, has the capability to model daylighting in spaces. This tool can be used for both compliance calculations and for cost effectiveness calculations. Other daylighting tools provide a detailed, point-by-point lighting assessment for an instant in time. These include LumenMicro, Radiance and LightScape.

Relationship to Other Measures

This measure will be coordinated with other lighting control measures and the revised definition of daylit area.

Bibliography and Other Research

The veracity of this idea is supported by the *Advanced Lighting Guidelines*. Costs were determined during work on the Collaborative for High Performance Schools (CHPS) project

Lighting: Exterior Lighting

Description

This change makes high efficacy lighting required for most exterior lighting applications. This requirement would replace the 60 lumens per Watt efficacy requirement added with the AB 970 changes.

> *Exterior lighting shall employ high efficacy source(s). Luminaires shall not be equipped with a screw (Edison) base.*
>
> *Exceptions:*
>
> *1. In climate zones 14 or 16, luminaires with lamps rated less than 60 Watts.*
>
> *2. Low voltage luminaires rated 50 watts or less.*
>
> *3. Luminaires directly controlled by a motion-sensing device.*
>
> *4. High intensity discharge luminaires may employ a medium or mogul screw base.*
>
> *5. Lighting used in or around swimming pools, water features, or other locations subject to Article 680 of the 1998 California Electrical Code,*
>
> *6. Lighting that is integral to advertising signage.*
>
> *7. Lighting required by a health or life safety statute, ordinance, or regulation, including but not limited to, emergency lighting,*
>
> *8. Searchlights and lighting for use in theme parks.*
>
> *9. Outdoor theatrical equipment provided it is for temporary or periodic use and is not for continuous use.*

Benefits

Energy savings can be substantial. Since HID and CF lamps are commonly used in many applications, this would require only marginal applications to comply, but the connected Watts are considered substantial.

Environmental Impact

This requirement will have no negative environmental impacts.

Type of Change

This would be a mandatory measure. It would need to be described in the Manuals.

Measure Availability and Cost

See the residential standard proposed above. In general, commercial facilities use HID and other high efficacy sources because of energy costs.

Useful Life, Persistence and Maintenance

These measures will persist, saving maintenance and extending life.

Performance Verification

The power savings and benefits of this measure are well established and have been promoted by the *Advanced Lighting Guidelines* since 1990.

Cost Effectiveness

This measure will increase the cost of construction by about $1.50 per square foot, on average. It will permit the reduction of power by 0.6 W/ft^2, on average, resulting in demand savings as well as kWh savings. Assuming this measure applies to 3,000 operating hour locations, the average energy savings will be about 1.8 kWh per year. It will save about $0.25/ ft^{2}per year, making the simple payback period about six years.

Analysis Tools

The critical analysis is the relative cost of dimming ballast equipment, which will be needed to implement this requirement.

Relationship to Other Measures

This matches the residential standard in form and intent, and uses the new definition of high efficacy lighting.

Bibliography and Other Research

The veracity of this idea is supported by the *Advanced Lighting Guidelines*.

Lighting: Common Lighting Systems

Description

This change would provide a simplified method for complying with the nonresidential lighting power allowances, based on a sub 1.0 W/ft² method using common lighting systems. §146 would be modified to include the prescriptive requirement. Alternatively, they might be included in the ACM Manual or even the Nonresidential Manual. The following is possible language that might be added to the *Standards* if the requirement is implemented that way.

§146 – Prescriptive Requirements for Interior Lighting

A building complies with this section if either:

The building employs specific lighting systems applied in the manner permitted by Subsection (a); or The building's actual lighting power density calculated under Subsection (b) is no greater than the allowed lighting power density calculated under Subsection (c).

(a) Specific Common Lighting Systems All luminaires used in the building shall comply with Subsections 1 through 6.

1. Permitted Building Types This method may only be used to demonstrate compliance for buildings listed in Table 1-M having a minimum allowed power of 1.0 w/ft^2.

2. Permitted luminaires Luminaires shall consist of any of the following. Spacing measurements are taken from the plan view center of the luminaire:

a. One single lamp luminaire employing a fluorescent lamp not exceeding 35 input Watts may be installed in a closet, electric room or other small space.

b. Recessed or surface mounted fluorescent troffers, wraparounds, strip lights, or other nominal 4' long luminaires having (1) or (2) lamps and not exceeding 60 input Watts, with luminaires no closer than 8' in any direction, center-to-center.

c. Suspended fluorescent uplights, industrials, wraparounds, strip lights, or other nominal 4' lamps having (1) or (2) lamps and not exceeding 60 input watts, with luminaires in continuous rows no closer than 15' apart.

d. High intensity discharge or induction lamp lighting systems consisting of 100 lamp watt luminaires no closer than 12' in any direction center-to-center; 150 lamp watt luminaires no closer than 15' in any direction center-to-center; 250 lamp watt luminaires no closer than 18' in any direction center-to-center; or 400 lamp watt luminaires no closer than 22' in any direction center-to-center.

e. Compact fluorescent downlights, wallwashers, monopoints and similar directional luminaires not exceeding 35 input watts, with luminaires no closer than 6' in any direction, center-to-center; luminaires not exceeding 60 input watts, with luminaires no closer than 8' in any direction, center-to-center; or luminaires not exceeding 90 input watts, with luminaires no closer than 10' in any direction.

f. When mounted underneath permanent overhead cabinets, hardwired fluorescent undercabinet lights 2', 3' or 4' in length and employing an electronic ballast.

g. Low-voltage downlights, accent lights or monopoint lights, having an integral transformer and rated at 50 watts or less, with luminaires no closer than 8' in any direction, center to center.

h. Compact fluorescent sconces, pendants and other decorative lighting not exceeding 90 input watts with luminaires no closer than 10' in any direction, center-to-center.

i. Exit signs rated less than 5 watts input power.

3. Spacing Of Luminaires In addition to spacing between luminaires specified above, luminaires shall be located within a space as follows:

a. When different types of permitted luminaires are adjacent to one another in the same space, the spacing between luminaires shall be the larger of the required spacing for the luminaires.

b. Luminaires shall be no closer to a wall or partition than ½ of the specified center-to-center distance.

4. Prohibited luminaires None of the following luminaires shall be employed in the building:

a. Luminaires designed for incandescent or halogen line voltage lamps.

b. Luminaires designed for incandescent or halogen low voltage lamps exceeding 75 watts.

c. Track lighting systems of any kind or voltage of operation.

d. Line voltage monopoints permitting the installation of track luminaires.

Exception: Emergency lighting systems required by code and not used except in under power outage or emergency conditions.

5. Permanent Lighting A complete and permanent lighting system shall be installed. Additional lighting, such as lighting within furniture systems, shall not be installed in the space.

6. Inspecting Authority Option If in the opinion of the inspecting authority the lighting installation does not sufficiently comply with this section, he/she may require compliance documentation using option (b) of Section 146.

Benefits

This change provides an option to reduce the cost of compliance and eases inspection for basic lighting installations. The power savings and benefits of this measure are simple. By providing effective patterns of lighting design operating at 1.0 W/ft^2 or less, this method ensures compliance with existing power limits with at least a 10% margin.

Environmental Impact

There is no negative environmental impact associated with this measure.

Type of Change

This would be a new prescriptive compliance option in §146.

Measure Availability and Cost

There is no cost for implementing this measure. It will save cost for contractors who need to comply with the Standards.

Useful Life, Persistence and Maintenance

This measure has no significant effect on the life, persistence, and maintenance of lighting by the owner. The equipment needed to comply using this method is not significantly different from that used for the lighting power allowance method. All of the proposed methods are specified to ensure an LPD of 1.0 W/ft^{2}or less, as follows:

a. 35 Watts maximum in a small space is not an issue

b. 60 Watts, 64 ft^2, 0.9375 W/ft^2

c. An area will be at least (15x4) = 60 feet per luminaire plus (11X15)= 165 ft^2. In theory, the maximum power density is just under 1 W/ft^2.

d. 100W lamp, 122 W input, 144 ft^2, 0.84 W/ft^2; 150 Watt lamp, 186 Watt input, 225 ft^2, .826 W/ ft^2; 250 Watt lamp, 305 Watt input, 324 ft^2, .941 W/ ft^2; 400 Watt lamp, 456 Watt input, 484 ft^2, .942 W/ ft^2.

e. 35W/36 ft^2; 60W/64 ft^2; 90W/100 ft^2

f. Permanent overhead cabinets are rare, not an issue

g. 55va/64 ft^2 including transformer loss

h. 90w/100 ft^2

Performance Verification

No performance verification is needed.

Cost Effectiveness

This measure will reduce design, compliance, compliance checking, and inspection costs. It is an alternative to the lighting power allowances and does not have to be cost effective.

Analysis Tools

This is a more prescriptive way of complying with existing lighting power requirements and no calculations are needed.

Relationship to Other Measures

This measure is intended to provide an alternative to compliance paths requiring calculations.

Bibliography and Other Research

The state of Washington employs a similar means of simplified compliance. This and other prescriptive methods will be evaluated as this proposal is further developed in subsequent tasks.

Lighting: Lighting Power Allowances –Complete Building Method

Description

This change will add space types to the complete building table (Table 1-M) and update some of the allowed Watts for some currently listed space types.

Benefits

This change may include parking garages as part of the lighting power allowances. A savings of 10% is likely for a number of existing applications. New standard non-conditioned spaces like garages have benefits expected to include at least 10% energy savings.

Environmental Impact

There is no negative environmental impact.

Type of Change

This would be a modification to existing prescriptive requirements. Changes would be made to Table 1-M.

Measure Availability and Cost

This will require research. It is generally believed that parking for garages tends to be relatively efficient already, but canopy lighting standards will probably reduce cost by imposing LPD limits.

Useful Life, Persistence and Maintenance

No significant change to current practices.

Performance Verification

There are no added requirements for performance verification.

Cost Effectiveness

The requirements will be shown to be cost effective using lighting models developed in subsequent tasks.

Analysis Tools

No additional analysis tools are needed. Point-by-point lighting calculations will be used in developing the models that are the basis of the LPD criteria. These methods may include LumenMicro, Radiance and/or LightScape.

Relationship to Other Measures

Adjustments to the whole building lighting power allowances will need to be consistent to the area category allowances and the tailored method.

Bibliography and Other Research

The *Advanced Lighting Guidelines* models demonstrate significant potential reductions in canopy lighting power, if proper lighting methods are employed. Other values would be based on models updated for 90 LPW fluorescent general lighting.

LPD values from 90.1-1999, LPD models as contained in the IESNA technical papers from the 90.1 committee, and modeling by CEC Staff and others will be needed to ensure that the LPD values are reasonable.

Lighting: Lighting Power Allowances – Area Category Method

Description

Table 1-N will be modified to include additional area categories or space types. It will also be updated to include advances in lighting technologies that have occurred since the last revisions.

Benefits

Additional area categories may include parking garages, loading docks, vestibules, and areas under overhangs and canopies. These are not currently regulated and additional energy savings will be achieved by including them. The change is estimated to save 10% energy for a number of existing applications. The new standard for exterior and non-conditioned spaces like garages can expect benefits of at least 10% energy savings.

Environmental Impact

There is no negative environmental impact associated with this change.

Type of Change

This is a modification to the existing prescriptive lighting requirements in §146, Table 1-M.

Measure Availability and Cost

This will require research. It is generally believed that lighting for garages tends to be relatively efficient already, but canopy lighting standards will probably reduce cost by imposing LPD limits.

Useful Life, Persistence and Maintenance

No significant change to current practices.

Performance Verification

There are no performance verification requirements.

Cost Effectiveness

These measures will be shown to be cost effective in subsequent tasks. Reduced lighting power may increase lighting equipment costs slightly, but these will be more than offset by energy savings. LPD values from 90.1-1999, LPD models as contained in the IESNA technical papers from the 90.1 committee, and modeling by CEC Staff and others will be needed to ensure that the LPD values are reasonable.

Analysis Tools

No additional calculation methods or tools are needed.

Relationship to Other Measures

The area category lighting power allowances will be made consistent with the whole building method and with the tailored method.

Bibliography and Other Research

The *Advanced Lighting Guidelines* models demonstrate significant potential reductions in canopy lighting power if proper lighting methods are employed. The models used to determine the IESNA lighting power allowances are documented at www.IESNA.org.

Lighting: Pulse Start Metal Halide Lamps

Description

This change would require that all new metal halide luminaires be "pulse start". This is an important technology with the following benefits.

- Metal halide pulse start systems offer 20-40% greater efficacy (initial and mean lumens per Watt) than ordinary "probe start" type.
- The small cost difference between the two would be eliminated and would prevent purchasing the ordinary probe start system.
- The change would help eliminate the confusion in the marketplace.

While this requirement is proposed for Title 24 and intended to apply only to new construction, the requirement should also be considered for the appliance efficiency standards of Title 20. As an appliance standard, the requirement would apply to all metal halide luminaires sold in California, regardless of whether they are installed in new buildings or not.

Benefits

This requirement will reduce energy use and emissions from power plants. It will generally permit the use of lower power rated luminaires. For instance, a 175 Watt pulse start metal halide is roughly equal to a 250 Watt probe start.

Environmental Impact

There is no negative environmental impact.

Type of Change

This change would be a mandatory measure. It would need to be described in the Manuals and it would probably be beneficial for the Commission to develop and disseminate a fact sheet to all electrical manufacturers and distributors, prior to implementing the measure.

Measure Availability and Cost

All major manufacturers of HID lighting in the U.S. produce pulse start products that meet this requirement. Cost differences between pulse start and probe start are relatively small.

Useful Life, Persistence and Maintenance

Probe start lamps tend to last longer, providing positive benefits with respect to the life, persistence and maintenance of lighting by the owner.

Performance Verification

There are no performance verification requirements.

Cost Effectiveness

This measure will be shown to be cost effective in subsequent tasks. Cursory reviews of a number of products shows a 15-25% increased in mean lumens with no increase in input Watts. The energy savings appears to easily amortize the small, added costs.

Analysis Tools

No additional calculation methods are needed for either compliance of life cycle cost calculations.

Relationship to Other Measures

There is no conflict with other Title 24 measures. There may be an overlap with pending federal standards.

Bibliography and Other Research

The benefits of pulse start technologies are well known and documented in the literature.

Lighting: Existing Lighting System Alterations

Description

Currently, §149 (Alterations) requires that lighting be compliant only if more than 50% of the existing lighting systems or circuits are modified.

However, lighting is the easiest building system to retrofit and bring into compliance at reasonable cost. This proposal would require that any alteration to lighting meet §131, §132 and §146 of the *Standards* for the entire space being altered.

An alternative proposal would be to require compliance with §131, §132 and §146 for any alteration where more than 50% of the existing lighting fixtures or circuits are modified, and also require compliance with §146 only for any alteration of more than 10%.

Benefits

By requiring energy efficient lighting in older spaces being renovated, this measure, in essence, requires a retrofit upon renovation, provided that the existing lighting does not meet the *Standards* already. The resulting renovation will use less energy than the previous, non-efficient system.

Environmental Impact

This measure can save considerable energy in older buildings being renovated.

Type of Change

This would be a mandatory measure, and would need to be described in the Manuals.

Measure Availability and Cost

Energy efficient lighting is not expensive. This measure would require work on existing lighting systems that might not otherwise be affected by a mostly superficial renovation.

Because many existing lighting systems are virtually compliant with the *Standards*, this change will not require any work in some cases. The primary impact will be on older buildings, where an energy efficiency retrofit is probably worthwhile anyway.

In general, retrofitting electric lighting costs about $\$1.00/ft^2$ to change from T-12/magnetic systems to T-8 systems, with similar costs for converting incandescent luminaires to compact fluorescent ones. Based on recent cost increases and the experience of retrofitting companies throughout California, the likely payback for this type of retrofit is about three years.

Useful Life, Persistence and Maintenance

This measure will be consistent with the existing life and maintenance qualities of these systems. The energy savings related to this measure will persist.

Performance Verification

Performance verification is not required for this measure, other than the standard plan check and field inspection.

Cost Effectiveness

Based on industry experience, lighting systems can be retrofit within a five-year payback, with the majority of systems being retrofitted within a three-year payback.

Analysis Tools

No further analysis tools would be needed to show compliance.

Relationship to Other Measures

This measure relates to measures concerning renovations.

Bibliography and Other Research

The *EPRI Lighting Retrofit Handbook* describes the many retrofits that can make existing lighting systems more energy efficient. The veracity of this idea is supported by the *Advanced Lighting Guidelines* and has been proven by the energy efficiency retrofit industry.

Lighting: Simplification of Tailored Method

Description

There are three methods to determine the lighting power allowance in nonresidential buildings: the complete building method, the whole area method, and the tailored method. The tailored method is most complicated since it is based on the IESNA system of illuminance categories. Lighting allowances depend on the IESNA illuminance task, the room cavity ratio (RCR) of the space, and for display lighting, the throw distance. The tailored method is most commonly used for retail lighting. In this case, a separate lighting allowance is produced for general illumination, wall displays, and feature displays. Rules have been introduced over the years to reduce the "gaming" opportunities from interpreting the IESNA illuminance categories. However, the procedures for retail lighting power density (LPD) have remained relatively unchanged since the mid-1980s. Compliance documentation for the tailored method must include plans and details typically not part of an electrical design drawing set.

This *Standards* change would simplify the tailored method to a table of standard lighting power allowances for retail spaces, more like the complete building or whole area methods. RCR or throw distance adjustments would continue to be a factor, but would be approximated by room size and ceiling height. One approach would be to develop a table of maximum LPD values for various retail store types. The tables would be based on the current tailored method with specific assumptions about geometry, useable wall area, etc. Use-it-or-lose-it could be applied by having a separate calculation for only those areas, preventing any unused watts from being utilized elsewhere or traded off against other building features. The support areas in retail occupancy, such as restrooms and corridors, would be determined either by a whole area allowance or by a retail general value that would be part of the retail table. The tailored method might remain for unique and unusual projects, although specific standards and comments should be updated to correspond with the *IESNA Ninth Edition Handbook*

The lighting power allowance table for retail spaces might look like the following:

Space type	Ceilings over 12 ft or spaces smaller than 3000 ft²	Ceilings over 15 ft or spaces smaller than 2000 ft²	Ceilings over 18 ft or spaces smaller than 1200 ft²
General retail	--	--	--
Grocery	--	--	--
Premium grocery	--	--	--
Clothing	--	--	--
Premium clothing	--	--	--
China and silver	--	--	--
Jewelry	--	--	--
Posters and gallery art	--	--	--
Fine art	--	--	--
Etc…….	--	--	--

Benefits

A revision of the tailored method would reduce compliance documentation and enforcement costs, especially for retail lighting. Since values in the proposed simplified table would be based on the current tailored method, the values will be the same or lower than the current standard.

Environmental Impact

This proposed measure is energy neutral and would have no significant environmental impacts.

Type of Change

Existing *Standards* language would be replaced under this change.

Measure Availability and Cost

This measure would not affect the cost or the availability of lighting systems.

Useful Life, Persistence and Maintenance

No significant change to current practices would occur with this measure.

Performance Verification

No performance verification is needed for this measure.

Cost Effectiveness

Since this measure does not change the allowed LPD but saves compliance costs, it is cost effective.

Analysis Tools

As a check, the tables would be tested against complying designs using the current tailored method. If the new method allows similar LPDs, it would be a suitable replacement.

Relationship to Other Measures

The compliance forms would have to be changed to embrace this revised method.

Bibliography and Other Research

The *IESNA Ninth Edition Lighting Handbook* revised the use and meaning of the illuminance categories, changing them significantly from the current *Standards*.

Lighting: Elimination of Controls Credits

Description

With the changes required by AB 970, automatic shut-off controls were made mandatory for all nonresidential buildings, effectively meaning that ALL spaces will be controlled by motion sensors, time clocks (including building automation), or timer devices.

The controls credits in the *Standards* aimed to use wattage incentives to encourage the use of these automatic control devices. Now that the controls devices are mandatory, the incentive is not needed and the control credits for these measures will be eliminated. However, controls credits would continue to be used as incentives for underutilized controls, such as fluorescent and HID dimming, demand limiting devices, and automatic daylighting systems.

Benefits

This measure would promote lower lighting power density. In addition to other reductions, a motion sensor currently permits a 20% net power reduction from the connected load in a small space, and a 10% reduction in a larger space. By eliminating these controls credits, designers would have to design lighting systems whose actual Lighting Power Density (LPD) meets the requirement.

Environmental Impact

This change will produce a net reduction in connected lighting power of up to 15%, which is the current amount of power these controls credits permit for automatic lighting controls versus manual only controls.

Type of Change

This mandatory measure change would need to be described in the Standards and Manuals.

Measure Availability and Cost

This measure should have no significant cost and, in fact, may promote savings by reducing lighting equipment costs.

Useful Life, Persistence and Maintenance

This measure will not change the existing life and maintenance of these systems. The energy savings related to this measure will persist.

Performance Verification

Not Applicable

Cost Effectiveness

This measure will result in the use of either less lighting equipment, or more advanced technology, e.g. T-5 instead of standard T-8 light sources. The energy savings can be tested against the added costs for the latest generation of lamp and ballast technology.

Analysis Tools

It is recommended that various designs using T-8, T-5, HID, and other light sources be analyzed for energy use and life-cycle costs to ensure the cost effectiveness of this measure. There is no need to analyze energy savings.

Relationship to Other Measures

If this measure is included, it is recommended that reductions in all LPD values (Tables 1-M, 1-N, etc.) not be made solely on the basis of T-8/T-5 system efficacy improvements.

Bibliography and Other Research

ASHRAE/IES 90.1 adopted this approach due to the advancement of lighting controls. The *EPRI Lighting Controls Patterns* book demonstrates the effectiveness of this method and the *Advanced Lighting Guidelines* confirms the increased systems efficacies.

Lighting: Elimination of Exemption for Normally-on Emergency Systems

Description

This proposed change provides more explicit language in the standards to clarify that exitway or egress lighting, whose switching is regulated by Article 3-700 of the California Electrical code is only excepted from being included in the lighting power density calculation when it is not used for ordinary lighting of spaces. The Commission has previously made this clarification, which will be included in the 2001 Nonresidential Manual.

Lighting that illuminates the path of egress can not be switched off and is not included in LPD calculations when it is lighting that is not used for ordinary lighting.

Benefits

This measure will clarify the existing standard.

Environmental Impact

This change could result in a slight reduction in the power density of public spaces.

Type of Change

This mandatory measure would need to be described in the Standards and Manuals.

Measure Availability and Cost

This measure seeks to prevent LPD gaming, and therefore is believed to have no cost implications.

Useful Life, Persistence and Maintenance

This measure has no known impact on useful life, maintenance, or persistence.

Performance Verification

Not applicable.

Cost Effectiveness

Not applicable. There is no change in the requirements.

Analysis Tools

No calculation tools are needed. The allowed LPDs for all spaces have been modeled and offer adequate illumination.

Relationship to Other Measures

This measure should not reflect on any other measure.

Bibliography and Other Research

No research appears to be required for this change.

Other: Performance Verification of Nonresidential Systems and Equipment

Description

Although many new buildings in California meet or exceed the energy code[3], there is a significant gap between the intent of the design and actual building performance. A study of 60 commercial buildings found that more than half suffered from control problems, 40% had problems with HVAC equipment, and one-third had malfunctioning sensors. An astonishing 15% of the buildings studied were missing specified equipment, and approximately 25% of them had malfunctioning energy management control systems (EMCS), economizers, and/or variable speed drives.[4] Performance verification is aimed at reducing these problems in new buildings constructed in the state of California.

Performance verification can more effectively ensure code compliance and help determine whether equipment meets operational goals or could be adjusted to increase efficiency and effectiveness. It has three basic elements that will be included in code requirements:

- Documentation that will enable the installation of monitoring points used in the verification of measure performance,
- Test requirements that determine if an installed system or equipment meets the intent of the code, and
- Requirements for who is allowed to perform the tests to verify performance.

This process will be implemented through certified third-party entities. These individuals will be responsible for performing both plan review and field verification to certify the performance of measures required by the *Standards*. For some measures, the Building Automation System (BAS) may be utilized as a tool for performing measure verification.

Benefits

Verifying the performance of measures will produce both energy and non-energy benefits.

The energy benefits will be assessed through a process of analyzing the measure in a failure mode, and then in a normal operational state. Each measure will then be assigned two probability values: one for normal operation and one for failed state. A model will be developed using the Nonresidential New Construction Database to determine statewide impacts based on these failure modes, and the net-present value (NPV) of the cost of failures will be identified. This work will be done in conjunction with the other 2005 *Standards* analysis.

For example, a preliminary analysis of economizer failures by PG&E shows a NPV of $187 million statewide, or $6,500 per HVAC unit, assuming that 10% of economizers fail while open, with the remaining units failing in the closed position (100% overall failure rate).

The non-energy benefits associated with verifying the performance of measures include improved health and safety, reduced environmental distractions, and a more comfortable building that may result in improved worker satisfaction.

Environmental Impact

This measure will not have any adverse environmental impact.

[3] This refers to the Energy Efficiency Standards for Nonresidential Buildings contained in Title 25, Part 6 of the California State Building Code.

[4] PECI. 1997. *Commissioning for Better Buildings in Oregon.* Oregon Office of Energy.

Type of Change

Mandatory Measure	This change would require all plans to identify specific monitoring points that will facilitate verifying the performance of a measure.
Prescriptive Requirement	This change would require two types of changes to the prescriptive approach. The first change would require that if the following measures are installed for credit, they then pass certain tests to verify their performance: ▪ Chilled Water Systems ▪ VAV Systems ▪ Package HVAC Systems ▪ Air Distribution Systems ▪ Lighting Controls ▪ Economizers The second change would require alternative performance criteria for some measures that would increase their potential to performing correctly in the absence of specific tests. For example, higher efficiency package HVAC equipment could be required in lieu of verifying economizer performance.
Compliance Option	The change would add a new compliance option. This option would have to be implemented in the ACM to account for the impact of reduced measure performance if the verification option is not selected.
Modeling	If performance verification is not required when using the performance approach, the certified programs would have to allow the derating of measure performance, should the verification option not be selected.
Other	The administrative chapter of Title 20 will be modified to describe the process necessary to certify providers who will verify measure performance. In addition, new compliance documentation requirements would be added.

Measure Availability and Cost

Third-party providers will enforce this requirement. The model being considered is similar to the CHEERS model for verifying duct performance in residential buildings. Because the option exists to comply without verifying performance (via enhanced efficiency in measure alternatives or other parts of the building), there will be a phasing-in period for the list of certified third parties. In addition, the recently formed California Commissioning Collaborative will work to develop this group of providers.

The baseline condition will vary by measure. For economizers, the baseline condition will be a minimum efficiency unit, with no economizer. The enhanced condition will include the cost of the economizer, plus the cost to perform the verification. Lighting controls and air distribution systems will be similar. For VAV and chilled water systems, performance verification may be required, and the costs would be based on using BAS for trend logging.

Costs for performing verification will be developed by monitoring utility-sponsored pilot programs, having existing commissioning providers give cost estimates, and through current residential duct sealing programs.

Useful Life, Persistence and Maintenance

The life and persistence of measure performance is an issue that touches all parts of the *Standards*. While a one-time verification process may deliver long-term savings over the life of some measures, it may not assure that other measures will deliver long-term savings.

For more sophisticated large-scale buildings and systems, a one-time, pre-occupancy performance check is far less likely to yield persistent savings. An example of this is chilled water plants where performance and efficiency is variable and highly dependent upon load, and chilled and condenser water temperature. Performance verification will only assure that long-term savings are not impacted by improper installation and start-up.

For these systems, the building owner could use BAS, which is already a part of the building project, as a means of verifying performance. By allowing this compliance method, it is possible to set the stage for continuous commissioning, performance verification, and diagnostics procedures over the life of the building and its systems.

Performance Verification

This proposal defines the requirements for performance verification.

Cost Effectiveness

It is key to realize that the savings for the measures requiring verification are an inherent part of the entire measure savings.

Therefore, performance verification does not have to be cost-effective on its own, but as a package when considering the cost of the measure, cost of verification, and savings associated with the measure. This approach will be used to determine the cost-effectiveness of the performance verification process. The process itself will not be subject to a separate cost-effectiveness analysis, independent of measure savings.

Analysis Tools

The current reference method is capable of providing results for the proposed approach. This method uses a probability function to estimate failure and proper operation. If the status of a broken system is something other than the absence of the measure (or a failure mode that falls outside current tool capabilities), then additional analysis tools may be necessary.

Relationship to Other Measures

This measure will impact the cost-effectiveness analysis and language of the measures that may be proposed by others for:

- Chilled Water Systems
- VAV Systems
- Package HVAC Systems
- Air Distribution Systems
- Lighting Controls
- Economizers

Bibliography and Other Research

Nonresidential Quality Assurance Project. *Verifying the Performance of New Nonresidential Buildings*, Final Report, April 30, 2001. www.newbuildings.org/downloads/codes/NRQAreport.pdf.

Johnson, J and Potter, A. *Incorporating a Method of Verifying Performance into California's Nonresidential Energy Standards: Opportunities and Obstacles*, National Conference on Building Commissioning, May 2001, PECI, Inc.

OTHER MEASURES

Reconsideration of Climate Zone Boundaries

Description

This *Standards* change would adjust the climate zone boundaries in a few targeted locations in California. Two areas of concern exist: along the coast in San Diego and in the interior valley south of San Jose. There is a great deal of construction activity in both places.

San Diego County includes four climate zones: 7, 10, 14, and 15. These form bands as you move from the coast inland. In San Diego County, the concern is that climate zone 7, which is a coastal climate with a strong marine influence, extends too far inland. In other words, some of the land area that is currently in climate zone 7 should actually be in climate zone 10. Residences in climate zone 7 are generally not air conditioned, while those in climate zone 10 usually are air-conditioned. The position of the boundary is an issue, because if portions of climate zone 7 are hot enough for air conditioning, then the *Standards* are not doing enough in terms of solar control or air conditioning.

The issue south of San Jose is similar, but a little more complicated. San Jose adjoins the San Francisco Bay and has some marine influence, although not as much as Oakland or Berkeley, which are more in the path of summer fog. Homes in San Jose really do not need air conditioning and traditionally, they have been constructed without it. As you move south of San Jose into the cities of Morgan Hill and Gilroy, temperatures are hotter and most, if not all, homes have air conditioning.

The reference city for climate zone 4 is Moffett Field, which is located on the San Francisco Bay and enjoys a marine influence similar to San Jose. This climate data is probably appropriate for the south bay area, but the problem is that climate zone 4 extends south for about 200 miles, all the way into northern Santa Barbara country. While the climate date for Moffett field may be appropriate for the northern tip of climate zone 4, it is likely not appropriate for most of the rest of the climate zone.

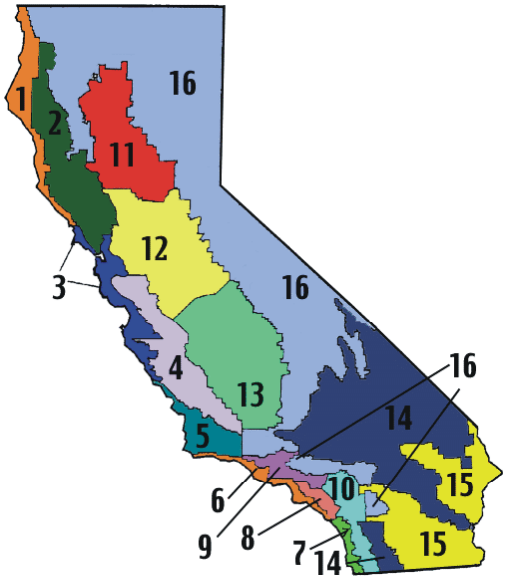


Figure 3 – California Climate Zones

Probably the best option for climate zone 4 is to find a new set of weather data to use with it that represents the warmer conditions typical for the majority of the landmass encompassed by the zone. If it is possible to find such data (should probably be similar to Santa Rosa, the reference city for climate zone 5, since they are both

in similar conditions), then it may also be desirable to lop off the northern portion of climate zone 4 and move it into climate zone 3, where Oakland is the reference city.

Benefits

The primary benefit of adjusting the climate zone boundaries is to assure that appropriate energy efficiency requirements apply. The requirements for climate zones 3 and 7 are appropriate for coastal climates where homes are not air-conditioned. If residences in these areas are being constructed with air conditioning, then this is a strong indication that they are located in the wrong climate zone. It also means that the prescriptive packages require an inappropriate set of energy efficiency measures. Adjusting the climate zone boundaries means that the state will realize more energy savings, and the additional energy savings will bring reduced atmospheric emissions and other associated benefits.

It is also significant that both regions (east of San Diego and south of San Jose) are marked by substantial building activity. As a result, a number of new buildings will now have to comply with requirements that are more stringent than those of the previous Standards.

The San Diego region was designated as a focus area for demand reduction, due to transmission constraints in the area. This new measure will greatly help in achieving this demand reduction.

Environmental Impact

Adjusting the climate zone boundaries would result in reduced energy use, and a number of environmental benefits are associated with reduced energy use. There are no negative environmental impacts.

Type of Change

This is a modeling change, but it will also modify the requirements in some locations that are moved from one climate zone to another. A different set of prescriptive packages and energy budgets will apply to the regions that will be affected. However, this measure will probably not require any changes to these requirements. With the AB 970 changes, climate zone 2 was grouped with climate zones 11, 12, and 13 for expressing the nonresidential standards. A possible result is that climate zone 4 could join this group.

The measure will require changes to California Climate Zone Descriptions (July 1995) and Figure 1-A of the *Standards*. Changes to Appendix C – California Design Location Data of both the residential and nonresidential manuals will also be required. The compliance forms will not change as a result of this measure.

Measure Availability and Cost

This measure does not add any new requirements. No additional cost is associated with this measure.

Useful Life, Persistence and Maintenance

There are no issues related to persistence or maintenance for this measure.

Performance Verification

No performance verification is needed for this measure.

Cost Effectiveness

There is no cost associated with this measure. However, new weather conditions may change which measures become cost effective in climate zone 4.

Analysis Tools

No additional analysis tools are required for this measure.

Relationship to Other Measures

This measure is independent of other measures.

Bibliography and Other Research

The CEC climate zones are documented in a couple of places. Both the residential and nonresidential ACM Manuals have a list of California cities with an indication of which climate zone each city belongs to.

Climate date is available from NOAA, PG&E, SCE, SDG&E and others.

A research approach under consideration is to collect information from building departments on the frequency of air conditioning in the areas under question. If the frequency is high, then this can be read as an indication that the climate zone boundary is misplaced.

Other proposed research will involve working with the CEC staff and local building officials to identify areas in the state where climate zone boundaries may be inappropriate. Available weather data for these locations as well as topographical maps that show ridges, canyons and other defining features will be collected. Building permit activity in the transition areas will be collected to enable the assessment of the importance of moving these boundaries. These and other data will be synthesized, and when appropriate, new climate zone boundaries will be proposed. The necessary documents will then be updated, including the climate zone map and city directories.

Time Dependent Valuation (TDV)

Description

Time dependent valuation (TDV) is an alternative to source energy as the currency for evaluating building energy performance. Unlike source energy, TDV accounts for *when* energy is used. Measures that save energy during periods when TDV is high will be credited more than measures that save energy when TDV is low. For electricity, TDV is high during hot summer afternoons and low during colder temperatures, typically at night. TDV is intended to track real-time electricity prices.

For gas and propane, the variations are more seasonal, with values lower in summer and higher in winter. TDV values closely mirror the prices that consumers pay for energy and more accurately reflect the monetary benefits to building owners from energy savings. TDV would be implemented in approved performance calculation methods. No additional inputs or data requirements would be necessary for using programs that incorporate TDV. The ACMs would look essentially the same.

TDV would affect both the residential and nonresidential *Standards* and would affect the way all measures are credited in the compliance process when the performance method is used.

Benefits

Insofar as the performance standards are used to optimize energy performance, using TDV would produce buildings that have smaller peak power requirements. Since energy used during peak periods is valued more, a premium would be placed on saving it. The corollary is that measures increasing energy consumption when TDV is high would be penalized, and it would be more difficult to achieve compliance with such measures.

Buildings optimized under TDV would be less expensive to operate since more energy would be saved during periods when prices are high.

Environmental Impact

If TDV results in a shift in consumption from peak periods to off peak periods, then this would reduce the use of peaking plants and increase the use of baseload power plants.

Type of Change

TDV would be implemented primarily as a modeling change. The TDV rules would be documented in the Residential and Nonresidential ACM Approval Manuals. In addition, the *Standards* would need to be updated in several places, as shown below:

- §101 Definitions has terms for Energy Budget and Source Energy that would need to be modified.
- §102 Calculation Of Source Energy Consumption would need to be modified. This section has Table 1-B with the source energy conversion rates.
- The term source energy or source energy consumption is used throughout the *Standards*. This would be changed to TDV energy or to another suitable term.

The ACM rule changes would include detailed data on TDV multipliers or TDV energy for each hour of the year. TDV will also likely vary with climate and building type (residential vs. nonresidential). A considerable amount of data is contained in the current TDV proposal. It would be best if this data were distributed through electronic means rather than by publishing it in the ACM Manuals. The electronic documents would then become an extension of the print documents.

Measure Availability and Cost

The ACM vendors would implement TDV. EnerComp is the program vendor for MICROPAS. EnergySoft is the program vendor for EnergyPro. These program vendors have the market share for residential and

nonresidential compliance software, respectively. EnerComp already has a research version of its program that implements TDV. No version of EnergyPro directly implements TDV, but the program has the capability to create output files that can be processed by TDV spreadsheets.

The ACM program vendors already update their software every three years to address regularly scheduled code changes. TDV would be one more code change that would need to be addressed on the normal three-year cycle. Many other code changes have taken place in the past, which have triggered ACM changes comparable to TDV.

TDV would also need to be implemented in the CEC "public domain" computer programs for residential and nonresidential standards. This would be the responsibility of the CEC staff or its contractors.

Useful Life, Persistence and Maintenance

N/A

Performance Verification

N/A

Cost Effectiveness

This topic is not applicable for TDV as long as TDV is only used in the compliance process. Some have proposed that TDV also be used to show that the standards are cost effective. If TDV is used to determine the *Standards* cost effectiveness, then measures that are more effective at reducing energy during peak periods would more likely be included in the *Standards*. Ultimately, the mix of requirements and measures included in the *Standards* could morph to a new set that is more sensitive to peak energy consumption.

Analysis Tools

TDV is not a measure, like wall insulation, that needs a tool to analyze it. TDV is itself a tool, which would be implemented in ACMs (see above).

Relationship to Other Measures

TDV affects all measures used for compliance or considered to be included in the *Standards*.

Bibliography and Other Research

Much of the research on TDV was supported by PG&E. Two reports are available as shown below:

- Time Dependent Valuation of Energy for Developing Building Efficiency Standards, Summary Report, December 6, 2000.
- Dollar-Based Performance Standards For Building Energy Efficiency, Final Report, March 25, 1999.

Photovoltaic Systems

Description

This change would add calculation procedures to the Residential and Nonresidential ACM Manuals to enable consideration of photovoltaic (PV) systems in the code compliance process. Both the residential and nonresidential *Standards* currently permit consideration of PVs, but the ACM Manuals provide no details on how the benefits would be calculated. The following are excerpts from §140 (nonresidential) and §151 (residential). Emphasis is added.

> §140 – Choice Of Performance And Prescriptive Approaches
> The envelope and the space-conditioning, lighting, and service water-heating systems of all nonresidential, high-rise residential, and hotel/motel buildings subject to Title 24, Part 6, shall be designed, constructed, and installed either: (a) Performance Approach — to use no more source energy from depletable sources than the energy budget, calculated according to Section 141; or (b) Prescriptive Approach — in accordance with all the applicable requirements of Sections 142 through 146.
>
> §151 (e) 4
> The total calculated annual energy consumption need not include energy from any nondepletable sources, regardless of the purpose of the energy consumed.

Although PVs are not specifically mentioned, the *Standards* are clear that any energy from nondepletable sources does not need to be considered in calculating the energy use of the proposed design. This provides a credit for PVs to offset any energy use included in the energy budget, e.g. water heating, heating, cooling, lighting, or ventilation. Section 3.5.2.17 of the Nonresidential ACM Manual addresses "Renewables," but only mentions solar thermal water heating by name. Any statement regarding renewable energy systems includes PV systems. The document says, "ACMs shall not model renewable energy sources for any of the standard design energy use." This sentence implies that renewable energy systems may be modeled in proposed design.

Benefits

The energy produced by PV systems is “clean” energy, meaning it does not contribute to air pollution or produce any greenhouse gases. Energy from PV systems also displaces power that would normally be provided by the grid. This would reduce demand during peak periods and address the electricity crisis in California. Air quality benefits can be quantified in tons of reduced emissions.

The TDV proposal may benefit the use of PV systems to a certain extent. The peak output of PV systems typically occurs 2-3 hours in advance of peak demand. PV systems generally produce 60% to 80% of maximum during peak periods.

Environmental Impact

Some concerns surround the use of toxic heavy metals during the manufacturing processes for certain types of PV cells. However, as a whole, the PV industry is considered superior to fossil fuels with respect to environmental impact.

The embedded energy of the manufacturing process is comparable to common industrial processes.

Type of Change

No changes are necessary in the *Standards,* since they currently permit consideration of PVs as well as any other renewable energy resource. PVs would be implemented through modifications to the ACM Manuals, where procedures would be added for calculating benefits.

It may also be necessary to add eligibility criteria regarding new equipment, specifically PV panels and inverters. These requirements would assure that the equipment is reliable, correctly installed, and performance

verified, so that energy savings will be persistent for the life of the building. Other restrictions on the type of tradeoffs allowed may be placed in the *Standards* or the ACM Manuals.

Market Characteristics and Cost

The two main components of a grid-connected PV system are the cell modules and the power inverters. The following table lists the manufacturers in the market.

Table 2 – PV Manufacturers

Principle Manufacturers of PV Modules	***Inverter Manufacturers***
BP Solar	Xantrex
Astropower	Aerovironment Inc
Solarex	Trace Engineering
United Solar Systems Corporation	
Kyocera	
Siemens Solar Industries	
Evergreen Solar	
PowerLight Corporation (Building Integrated PVs)	

PV modules are generally only available through specialized contractors. However, some modules can be purchased from retailers, such as Real Goods and Palo Alto Hardware. Due to the recent influx of PV system orders, there has been some concern regarding the availability of certain components, such as PV panels. However, most solar contractors do not view supply as a problem.

PV systems cost from $8-$12/W installed, including both the panels and the inverters. If battery storage is added, this will further increase cost. The CEC Renewable Energy Program provides rebates of $4.50/W on a limited basis for customers in PG&E, SCE, SDG&E, and Bear Valley Electric territory. Municipal utilities do not pay into the Renewable Energy Program, and thus their customers are not eligible to receive rebates through this program. In April 2001, Governor Davis approved legislation that will provide $8 million in rebates for customers of municipal utilities. This particular program is still in the planning stages.

Life, Failure Rate and Commissioning

Photovoltaic modules generally come with a 20 to 25-year warranty from the manufacturer. Many systems installed during the 1970s are still in operation today. Accelerated lifespan testing at the Jet Propulsion Laboratory suggests that life span could be as long as 80 years. As long as the system is functioning, it will be displacing energy that would otherwise be provided by the grid.

The CEC Renewable Energy Program currently has a protocol regarding PV system components and installation for systems receiving buy down monies from the "Emerging Renewables Resource Account". The CEC website lists acceptable PV modules and inverters. Qualifying contractors must possess, or employ subcontractors who possess, an "A", "B", C-10, or C-46 license.

Performance Verification

The extent and type of commissioning for PV systems is dependent upon the panel configuration, the type of installation, and the stage that the project has reached. It is sometimes difficult to determine whether or not the system is operating optimally, and therefore, a specialist in PV commissioning may be needed. A pre-determined commissioning checklist should be developed for each stage of construction. Tests range from verifying the operation of individual panels to confirming proper power tracking by the DC-AC inverters.

Cost Effectiveness

Payback periods are very dependent upon location, but generally range between 15 and 30 years. The LCC analysis should be performed using the standard 3% discount rate and the 30-year study period. The savings are based on the kWh produced by the system and the appropriate utility rate schedule. This is fairly simple if the schedule is flat rate, and more complicated if the rate has time-of-use charges. In applications where the peak demand is generally a function of air-conditioning requirements, PV systems can provide savings through peak load shedding. Since the hottest days normally coincide with an abundance of solar insolation, PV systems would help in reducing this load.

Analysis Tools

Empirical solar insolation data for several cities in California are available on the National Renewable Energy Lab (NREL) website. These data are given as monthly average daily values (kWh/m^2/day), but can be translated into hourly values using theoretical equations. (A good reference for the theoretical equations is the text, *Solar Engineering of Thermal Processes* by Duffie and Beckman). However, using the average values means the daily distribution of solar radiation, and thus the output of the PV system, will be the same for any given day of a particular month. Another approach is to use hourly solar data that is already contained in the CEC weather files and is commonly available for other energy simulation programs.

The following analysis tools are available and commonly used to assess the benefits of PV systems.

- PVWATTS is Internet-enabled software available on the NREL website. This software uses the aforementioned data and several user specified inputs to estimate the monthly energy production, and corresponding monetary value for a given PV system.
- PV-DesignPro (~$150), developed by Maui Solar Software, contains a suite of Windows 95, 98, and NT software designed to simulate photovoltaic energy system operation on an hourly basis for one year, based on a user selected climate and system design.
- PV Designer (~$300), developed by Siemens Solar, calculates hourly, daily, monthly, and annual kWh_{ac} production. This software is available for Windows operating systems.
- DOE-2.2 contains an hourly PV model.

Bibliography and Other Research

The following are excellent resources for additional reading on PVs.

- http://www.nrel.gov/ncpv/. The Department of Energy's National Center for Photovoltaics. This website contains a wide range of resources from PV basics to technical documentation.
- http://rredc.nrel.gov/solar/codes_algs/PVWATTS/. This site contains web-based software for estimating the monthly energy production and corresponding monetary value for a PV system in a given location.
- Duffie, J. A. and W. A. Beckman. *Solar Engineering of Thermal Processes 2nd Edition,* Wiley and Sons, New York (1991). This book was originally printed in 1976, but is still viewed as the best resource regarding the theoretical modeling of solar insolation.

Assuming that TDV is implemented, it would then be necessary to have PV algorithms that produce hourly results. If TDV is not implemented, the methods cited above would be adequate. The primary research task for implementing PVs would be to develop algorithms that product hourly results. An additional task would be to develop eligibility criteria, including performance verification requirements, equipment requirements, including possible certification by the CEC, and other restrictions on the manner in which PV tradeoffs are made.